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 INDUSTRI-PLEX SITE

REMEDIAL TRUST

WOBURN, MASSACHUSETTS

# **SUPPLEMENTAL SITE INVESTIGATION REPORT**

## **INDUSTRI-PLEX SITE WOBURN, MASSACHUSETTS**

*PREPARED BY*

**ROUX ASSOCIATES, INC.**

**CAMP DRESSER & MCKEE, INC.**

**ENVIRONMENTAL SCIENCE & ENGINEERING, INC.**

**ENVIROGEN, INC.**

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## EXECUTIVE SUMMARY

### I. Scope of the Supplemental Site Investigation

Data developed during the implementation of Groundwater/Surface-Water Investigation Plan (GSIP) at the Industri-Plex Site (Site) during the early 1990s indicated that Site-related groundwater constituents of concern (i.e., benzene, toluene, arsenic, and chromium) undergo certain transformations as they migrate in the aquifer away from suspected source areas and towards the Hall's Brook Holding Area (HBHA) Pond, and as groundwater passes through the sediment at the base of the HBHA Pond. To further evaluate the geochemical transformations that take place within the aquifer downgradient of the source areas, and thus the ultimate fate of constituents of concern (COCs) as groundwater discharges to the HBHA Pond, the Industri-Plex Site Remedial Trust (ISRT) has commissioned a multi-disciplined team of experts to conduct a Supplemental Site Investigation (SSI) at the Site. This team includes Roux Associates, Camp Dresser & McKee (CDM), Environmental Science & Engineers (ES&E), and Envirogen. Roux Associates provided groundwater expertise and team management. CDM provided geochemical and groundwater modeling expertise. ES&E provided environmental toxicology expertise, and Envirogen provided biochemical expertise.

The objectives of the SSI were to:

- evaluate current Site conditions;
- preliminarily evaluate COC mobilization mechanisms;
- investigate the nature and extent of the geochemical and biological processes potentially affecting the discharge of COCs to the HBHA Pond; and
- develop an initial groundwater flow model which will serve as the basis for quantitatively representing hydrogeological and geochemical processes controlling COC fate and transport.

In scoping the SSI, the project team adopted a "source-to-sink" approach for investigating the various bio- and geochemical processes controlling COC fate and transport at the Site. This approach was adopted because the processes influencing COC fate and transport in

different areas of the Site (e.g., source areas, discharge areas, etc.) are often unique to those areas. Accordingly, the SSI was scoped as individual “work elements,” each of which was designed to focus on conditions and processes in discrete areas of the Site.

The SSI consisted of five separate work elements, each focusing on hydrogeologic and/or geochemical conditions in a particular media or portion of the study area, and proceeding in a “source-to-sink” fashion. The five work elements comprising the SSI include the following:

- Work Element 1 - source areas investigation;
- Work Element 2 - downgradient groundwater investigation;
- Work Element 3 - HBHA pond sediment (groundwater/surface-water interface) investigation;
- Work Element 4 - HBHA pond surface-water investigation; and
- Work Element 5 - HBHA wetland investigation.

The source areas investigation (Work Element 1) included evaluations of groundwater and soil geochemistry in the immediate vicinity of suspected source areas. This work was performed to further evaluate the mobilization mechanisms at the Site source areas, assess current geochemical conditions in source-area groundwater, and develop groundwater data to assist in calibrating the groundwater flow model being constructed as part of the downgradient groundwater investigation.

The downgradient groundwater investigation (Work Element 2) included evaluations of groundwater geochemistry and groundwater flow gradients in the area of the HBHA Pond, and development of a preliminary groundwater flow model for the Site and the area downgradient of the Site.

The HBHA Pond sediment (groundwater/surface-water interface) investigation (Work Element 3) included evaluations of sediment geochemistry, adsorption capacity, and biodegradation capacity. The data generated were used to evaluate the current and long-term environmental fate of COCs as groundwater discharges to the HBHA Pond.

The HBHA Pond surface-water investigation (Work Element 4) included an evaluation of surface-water geochemistry and a determination of the residence time of surface water within the pond.

The HBHA wetland investigation (Work Element 5) included evaluations of surface-water and sediment geochemistry, the adsorption capacity and biodegradation capacity of wetland sediment, and the residence time of surface water within the wetlands.

## **II. Significant Conclusions of the Supplemental Site Investigation**

Based on the findings of the various work elements conducted during the SSI, the environmental fate-and-transport conclusions set forth in the GSIP have been updated and expanded. Those expanded conclusions are presented below in a “source-to-sink” fashion, beginning with the mobilization of COCs at the suspected source areas, then describing the current and long-term fate and transport of the COCs as they migrate in groundwater away from source areas and to the HBHA Pond, where they are attenuated by HBHA Pond sediment as groundwater discharges into the HBHA Pond.

### COC Release Mechanisms in Source Areas

Based on the data developed during the GSIP and the SSI, it appears that the stockpiling of anaerobically-decaying hide residues atop arsenic- and chromium-containing soils during development of the Site in the late 1970s resulted in the creation of environmental conditions facilitating the mobilization of arsenic and chromium from the Site soils. Specifically, groundwater and precipitation percolating through the anaerobically-decaying hide residues is reduced through contact with the decaying hide residues. The reduced groundwater then infiltrates the arsenic- and chromium-containing soils underlying the hide piles, leaching arsenic and chromium from the soils, largely in the more mobile, reduced forms of these metals (e.g., arsenic III and organically-complexed arsenic and chromium compounds). The extent to which arsenic and chromium are leached from the metals-containing soils, and the forms of arsenic and chromium present in the leachate, are

controlled by the oxidation-reduction potential of the infiltrating water. Specifically, more arsenic and chromium are leached, and more mobile forms are produced, by water with lower oxidation-reduction potentials.

Presently, the source-area groundwater appears to be less strongly-reducing than it was during the GSIP, which was conducted between 1990 and 1992. Specifically, Eh conditions measured at source areas during the SSI increased compared to Eh's measured in source-area groundwater during the GSIP. This increase in oxidation of the source-area groundwater appears to be the result of one of two factors, or perhaps a combination of the two:

- site remedial measures (e.g., capping of the Site) implemented since completion of the GSIP in 1992 have reduced the amount of precipitation that infiltrates through the hide residues; and/or
- the amount of organic material available for leaching has decreased (via consumption) since the GSIP, which was conducted between 1990 and 1992.

The less reducing conditions present at the hide piles today appear to have resulted in less leaching of arsenic and chromium, and the production of generally less mobile forms of these metals. Specifically, arsenic and chromium concentrations detected during the SSI are generally less than those detected during the GSIP (C. 1990 - 1992), particularly at the West and East-Central Hide Piles, and at the Arsenic Pit. In addition, the majority of the source-area arsenic is now present in the oxidized, less mobile arsenic V form.

In addition to the arsenic and chromium sources, potential benzene and toluene source areas were also identified during previous investigations. These source areas include the following:

- a potential benzene source area located northeast of the South Hide Pile and directly south of Atlantic Avenue; and
- a potential toluene source area located near the southeast corner of the East-Central Hide Pile.

Despite extensive investigation during the 1980s and early 1990s using geophysical methods, soil borings, and temporary monitoring wells, no significant area of benzene soil contamination was ever found. Moreover, GSIP data, along with other data developed during the early 1990s, indicated that a benzene “hot spot” had migrated away from the potential benzene source area northeast of the South Hide Pile to an area adjacent to the northern end of the HBHA Pond. Benzene concentrations at the South Hide Pile and near the HBHA Pond appear to be generally the same today as they were during the GSIP. Toluene concentrations at the East-Central Hide Pile, on the other hand, appear to have decreased significantly since the GSIP (c. 1990 - 1992), suggesting a reduction in the strength of the toluene source in that area, or a reduction in leaching of the source area due to Site remedial measures completed since the GSIP.

#### Fate and Transport of COCs Downgradient of Source Areas

Once COCs have entered into the groundwater, their migration is governed by the groundwater flow regime at and downgradient of the Site. This groundwater flow regime is, in turn, controlled by surface-water features and the geometry of the underlying buried-valley aquifer. The buried-valley aquifer is characterized by a series of upgradient branch valleys underlying the Site which merge together into a main trunk valley in the vicinity of the HBHA Pond. Groundwater containing COCs moves downgradient down each of the branch valleys, and flows upward and discharges to surface water in the HBHA Pond. Apparently, but to a lesser extent (i.e., only for some of the groundwater migrating from the area of the West Hide Pile), some groundwater discharges to the New Boston Street Drainway (a tributary of Hall’s Brook and the HBHA Pond). Consequently, the HBHA Pond acts as the “endpoint” for the groundwater COC plumes migrating away from suspected source areas at the Site. This conclusion, that the HBHA Pond acts as the “endpoint” for the groundwater COC plumes at the Site, was first set forth in the GSIP and is supported by the water-level data developed for the area near the HBHA during the SSI. This conclusion is further supported by SSI groundwater modeling efforts, which indicate that, even with sensitivity-analysis changes in key variables, such as hydraulic conductivity of the aquifer and bedrock topography, modeled groundwater discharge from

identified suspected source areas is still to the HBHA Pond, or to the New Boston Street Drainway (a tributary of the pond) in the case of groundwater moving downgradient from the West Hide Pile.

As Site-related COCs migrate downgradient toward the HBHA Pond, they enter an area of the aquifer characterized by conditions more oxidizing than those present in the source areas. Here, arsenic and chromium concentrations in groundwater are attenuated (via adsorption and/or precipitation within the aquifer matrix) due to the change to more oxidizing conditions. More reducing conditions may exist, however, in limited areas of the aquifer, particularly at depth, where more of the organic matter from the source areas is present in groundwater. In these organic-material-rich areas of the aquifer, arsenic and chromium attenuation appears to be limited, as the arsenic and chromium remain in solution in reduced forms instead of being oxidized and adsorbing/precipitating out with iron hydroxides.

Little attenuation of benzene and toluene appears to take place in the aquifer downgradient of their suspected source areas.

#### Environmental Fate of COCs in Groundwater Discharging to the HBHA Pond

As groundwater discharges to the HBHA Pond, bio- and geochemical processes taking place in the pond sediment filter out or metabolize the COCs from the discharging groundwater, such that only low concentrations of dissolved COCs are present in pond surface water, and generally only at the base of the pond. A major conclusion of the SSI is that these processes continue today to effectively remove COCs from discharging groundwater.

The particular mechanisms responsible for the removal of COCs prior to groundwater discharge vary. Adsorption to iron-bearing pond sediment and co-precipitation with iron sulfates and iron hydroxides appear to be the mechanisms by which arsenic and chromium are attenuated. The role of organic carbon in sequestering arsenic and chromium appears

to be minimal. This represents a slight modification of the GSIP conclusion that chromium, in particular, complexed with sedimentary organic carbon in the pond sediment and was thus filtered out of the discharging groundwater.

Biodegradation appears to be the mechanism most responsible for attenuation of benzene and toluene. Biodegradation of benzene and toluene is believed to be occurring in the HBHA Pond sediment for the following reasons:

- a previous comparison of the benzene concentrations in groundwater beneath the pond with the benzene concentrations in surface water at the base of the pond (Roux Associates, 1995) indicated that greater than 90 percent of the mass of benzene discharging to the HBHA Pond is removed as groundwater moves upward through the pond sediment;
- benzene is known to be readily biodegradable; and
- GSIP studies showed that microbes in HBHA Pond sediment thrive on a benzene food source.

COCs adsorbed onto HBHA Pond sediment are generally retained in the pond, due to the relative quiescence of the pond bottom, which is, in turn, a function of the pond's morphology (i.e., the pond was designed as a storm-water retention basin). The pond's sediment-retention efficiency is demonstrated by the presence of over 1 foot of extremely fluid fine-grained sediment at the base of the pond, all of which has accumulated since the 1970s. However, based on the detection of COCs (i.e., arsenic and chromium) on suspended solids at the outlet from the HBHA Pond, some limited downstream transport of sediment-adsorbed COCs to the HBHA wetland appears to occur.

Residence times for surface water in the HBHA Pond and particularly in the HBHA wetlands appear to be too short to provide significant attenuation of any COCs that may periodically break through to surface water. However, no significant concentrations of COCs (i.e., greater than approximately 10 to 15 micrograms per liter) appear to migrate beyond the HBHA Pond and wetlands via the surface-water pathway.

### Long-Term Environmental Fate Issues

Based on adsorption-capacity “lifetime” calculations performed during the SSI, the HBHA Pond sediment appears to have an unlimited capacity (based on current trends in Eh/pH conditions) to attenuate chromium in discharging groundwater since potential chromium concentrations in pore water are limited by the relatively low solubility of the chromium precipitate present in the sediment. The sediment’s capacity to attenuate arsenic discharging to the pond is estimated to be at least several hundred years. However, additional arsenic adsorption will likely be accompanied by increased pore-water concentrations of arsenic. The sediment’s capacity to adsorb benzene was calculated to be less than 1 year, assuming no biodegradation processes occur. However, although not quantified during the SSI, biodegradation appears to be the dominant mechanism for benzene and toluene removal from discharging groundwater.

### Data Gaps

The SSI conclusions reflect the most current and comprehensive understanding of the environmental fate of COCs at the Site. Nonetheless, the SSI, together with the GSIP, suggest that some additional investigation is appropriate. The items warranting further investigation include the following:

- the trend toward less-reducing conditions at the source areas;
- toluene reductions in the suspected toluene source area;
- mechanisms for biodegradation of benzene in HBHA Pond sediments;
- potential remobilization of COCs in HBHA Pond sediment, particularly during storm events; and
- the source and extent of arsenic detected in the MC-3 MicroWell™ cluster.

## 1.0 INTRODUCTION

Data developed during implementation of the Groundwater/Surface-Water Investigation Plan (GSIP) at the Industri-Plex Site (Site) during the early 1990s indicated that Site-related groundwater constituents of concern (i.e., benzene, toluene, arsenic, and chromium) undergo certain transformations as they migrate in the aquifer away from suspected source areas and towards the Hall's Brook Holding Area (HBHA) Pond, and as groundwater passes through the sediment at the base of the HBHA Pond. To further evaluate the geochemical transformations that take place within the aquifer downgradient of the source areas, and thus the ultimate fate of constituents of concern (COCs) as groundwater discharges to the HBHA Pond, the Industri-Plex Site Remedial Trust (ISRT) has commissioned a multi-disciplined team of experts to conduct an Supplemental Site Investigation (SSI) at the site. This team includes Roux Associates, Camp Dresser & McKee (CDM), Environmental Science & Engineering (ES&E), and Envirogen. Roux Associates provided groundwater expertise and team management. CDM provided geochemical and groundwater modeling expertise. ES&E provided environmental toxicology expertise, and Envirogen provided biochemical expertise.

The objectives of the SSI were to:

- evaluate current Site conditions;
- preliminarily evaluate COC mobilization mechanisms;
- investigate the nature and extent of the geochemical and biological processes potentially affecting the discharge of COCs to the HBHA Pond; and
- develop an initial groundwater flow model which will serve as the basis for quantitatively representing hydrogeological and geochemical processes controlling COC fate and transport.

In scoping the SSI, the project team adopted a "source-to-sink" approach for investigating the various bio- and geochemical processes controlling COC fate and transport at the Site. This approach was adopted because the processes influencing COC fate and transport in

different areas of the Site (e.g., source areas, discharge areas, etc.) are often unique to those areas. Accordingly, the SSI was scoped as individual “work elements,” each of which was designed to focus on conditions and processes in discrete areas of the Site.

This report presents the findings and conclusions of the SSI. In keeping with the “source-to-sink” approach adopted by the project team, the SSI findings and conclusions presented in this SSI Report are reported in a similar, “source-to-sink” fashion, beginning with the mobilization of COCs at the suspected source areas, then describing the current and long-term fate and transport of the COCs as they migrate in groundwater away from source areas and to the HBHA Pond, where they are attenuated by HBHA Pond sediment as groundwater discharges into the HBHA Pond.

## **2.0 SCOPE OF WORK**

The SSI consisted of five separate work elements, each focusing on hydrogeologic and/or geochemical conditions in a particular media or portion of the study area, and proceeding in a “source-to-sink” fashion. The five work elements comprising the SSI include the following:

- Work Element 1 - source areas investigation;
- Work Element 2 - downgradient groundwater investigation;
- Work Element 3 - HBHA pond sediment (groundwater/surface-water interface) investigation;
- Work Element 4 - HBHA pond surface-water investigation; and
- Work Element 5 - HBHA wetland investigation.

Each of these work elements is described in detail below.

### **2.1 Work Element 1 - Source Areas Investigation**

The source areas investigation included evaluations of groundwater and soil geochemistry in the immediate vicinity of suspected source areas. *This work was performed to further evaluate the mechanisms of arsenic mobilization at the Site source-areas, assess current geochemical conditions in source-area groundwater, and develop groundwater data to assist in calibrating the groundwater flow model being constructed as part of the downgradient groundwater investigation.* The objective(s) and scope of each component of the source areas investigation are described in detail below.

#### **2.1.1 Groundwater Geochemistry**

Groundwater samples (GW-1 through GW-5) were collected by Roux Associates at points immediately downgradient of the West, East-Central, and South Hide Piles and the Arsenic Pit in order to assess current geochemical conditions in source-area groundwater and to calibrate the groundwater flow model being developed as part of the downgradient

groundwater investigation (Work Element 2). Source-area sampling locations are shown in Figure 1. Sampling locations GW-1 through GW-4 were situated at points where previous (i.e., GSIP) monitoring wells had been located, and each sample was collected from within the interval screened by its respective analogue well, in order to assess the temporal consistency of GSIP and SSI source-area groundwater geochemistry data. The respective GSIP analogue wells for GW-1 through GW-4 are listed below:

<u>SSI</u>		<u>GSIP</u>
GW-1	=	WP-5
GW-2	=	OW-43
GW-3	=	OW-16
GW-4	=	OW-54C

Due to the limited amount of geochemical data available for wells WP-5 and OW-54C, nearby wells OW-36 and OW-12 were also used for comparison with SSI data for sampling points GW-1 and GW-4, respectively. Sampling location GW-5 had no GSIP analogue well, but was situated not far from the former location of monitoring well OW-39.

The source-area groundwater samples were collected using Geoprobe™ technology, by hydraulically driving a slotted pipe into the saturated zone and extracting groundwater using polyethylene tubing and a vacuum pump. Groundwater samples were filtered in the field, and submitted to IEA, Inc. (IEA) of Billerica, Massachusetts for analysis (using Contract Laboratory Program [CLP] protocols where appropriate) of COCs and the following geochemical parameters:

- dissolved organic carbon (DOC);
- copper;
- zinc;
- sulfate;
- sulfide;
- nitrate;

- nitrite;
- ammonia;
- major cations (i.e., calcium, sodium, magnesium, potassium, and iron);
- major anions (i.e. carbonate/ bicarbonate, chloride, and fluoride);
- ferrous iron; and
- chromium species (Cr III/VI);

Unfiltered samples were also submitted to IEA for analyses of total copper and zinc, and total organic carbon (TOC). In addition, the groundwater samples were analyzed in the field for pH, Eh, dissolved oxygen (DO), temperature, and specific conductance.

Filtered samples of source-area groundwater were also submitted to Brooks Rand, Ltd. (Brooks Rand) of Seattle, Washington for analysis of arsenic species (i.e., arsenic III, arsenic V, organic arsenic, methylated forms, and total arsenic), and to Huffman Laboratories, Inc. (Huffman) of Golden, Colorado for DOC fractionation.

### **2.1.2 Soil Geochemistry**

Envirogen conducted a soil/hide-material column study designed to simulate, in a controlled laboratory setting, the reducing groundwater conditions previously indicated beneath the hide piles at the Site (Roux Associates, 1991; 1992), and to evaluate how such reducing conditions impact arsenic mobilization and speciation. The column study was also conducted to aid in the evaluation of measurements made at the Site during the SSI that indicated significant reductions in the concentrations of arsenic in source-area groundwater (see Section 3.1.1).

To simulate Site source-area conditions as closely as possible, a two-layer test column was constructed with hide-containing soils overlain with arsenic-impacted soils, in order to represent the spatial separation of these soils at the Site. Upgradient Site groundwater was passed in an upflow mode through the hide-containing soil at a rate comparable to the groundwater flow at the Site (2 feet per day; Roux Associates, 1991). In a further attempt to simulate Site conditions, the soil column and Site groundwater were maintained within a temperature range of 13° to 15° C.

Historical Site data suggested that significant arsenic mobilization would occur when highly reducing conditions were established in the test column, and that organic and arsenic III species would represent a significant portion of the total arsenic mobilized.

#### Collection and Transportation of Soil and Groundwater Samples

Groundwater and soil/hide-material samples for the laboratory study were collected using specific procedures designed to minimize changes in the *in situ* biological and geochemical parameters characteristic of the Site (anaerobic bacterial population, pH, DO, and oxidation-reduction potential [ORP]).

Samples of the hide residues were collected from the eastern portion of the East-Central hide pile (Figure 1). Split-spoon samples from two separate borings were collected from this location, each at a depth of 8 feet to 16 feet below land surface, and the split spoons were cut into 2-foot lengths for shipment and storage. The hide-containing soils were a deep black color with a pungent, musky odor characteristic of an anaerobic environment. Texture of this soil resembled a crumbled coal interspersed with what appeared to be hide fragments and hair. The uppermost material contained distinct layers of hair and hide fragments, while at increasing depths, the incidence of hair and hide diminished, and the matrix took on a coal-like appearance. Analysis showed that the hide residues contained a relatively low level of arsenic (18 milligrams per kilogram [mg/kg]) and that the pH was 6.5.

Arsenic-impacted soil samples were collected from the Arsenic Pit. Sample borings were drilled at three distinct locations to depths that ranged from 5 to 11 feet below land surface. Split-spoon samples from each location were composited to yield three separate samples, which were then transferred to glass jars for shipment and storage. The arsenic-impacted soil samples exhibited a distinct white color and a texture that resembled chalk. No distinct odor was noticeable. Arsenic was detected in the three composited samples,

with total arsenic concentrations ranging from 290 to 340 mg/kg. The pH was slightly depressed at 5.5.

The hide-containing soil samples were protected from geochemical/biochemical changes during sampling and shipment as described below:

- a two-inch diameter sampling tool (lined with an acetate sleeve) was used within a Geoprobe™ rig system to collect the soil material;
- prior to retrieval of the soil samples from the two-inch-diameter sampling tool, a stream of nitrogen was focused into an anaerobic sample bag kept under continuous positive nitrogen pressure;
- the soil cores were placed into this bag and cut into 2-foot lengths before sealing the exposed ends with plastic caps and tape; and
- during transport the soil cores were protected from sunlight and temperature extremes, and upon arrival at Envirogen's biotreatability laboratory in Lawrenceville, New Jersey, the samples were stored at 4°C.

The arsenic-impacted soils were collected in a similar manner, but were transferred to glass jars for shipment.

The groundwater sampling location was selected as upgradient of the East-Central hide pile, in the vicinity of former GSIP monitoring well OW-28 (Figure 1). Preserving the *in situ* redox state of the groundwater was the primary objective of the groundwater collection and transportation activities. Therefore, the groundwater was protected from geochemical alteration during sampling and shipment as follows:

- A low-flow peristaltic pump was used to create a constant flow of groundwater from the installed monitoring well. Prior to groundwater collection, the well was purged until the water's ORP and DO stabilized, indicating that representative groundwater was being removed.
- A carboy was placed in a black plastic bag and purged with nitrogen. Once the carboy was purged, nitrogen flow was directed into the plastic bag for purging. Nitrogen flow was continued into the plastic bag until the sampling was completed.
- Groundwater was pumped slowly into the bottom of the carboy, displacing the nitrogen out the top during filling. The carboy was filled using low flow groundwater

pumping techniques, and the headspace was again flushed with nitrogen immediately before sealing the carboy for shipment.

- During transport, the carboy was protected from sunlight and temperature extremes, and immediately upon arrival at the test laboratory the carboy was stored in the dark at 4°C.

The effectiveness of the preservation steps outlined above were verified by measuring DO, ORP, and pH on aliquots of the sampled groundwater during the column testing. The groundwater was kept in the sampling carboy, and its geochemical parameters were maintained at field values, as necessary, by periodically sparging with nitrogen gas.

#### Column Set-Up

The column used for this study was constructed from a 2-inch-diameter glass tube that was packed with 8 inches of the hide residue in the bottom and 10 inches of the arsenic-impacted soils in the top of the column. The column was approximately 2 feet tall and equipped with end caps drilled for the insertion of inlet and outlet ports. The ports allowed a continuous flow of groundwater through the columns (in an upward flow arrangement) at a rate of 1 milliliter (mL) per minute to be consistent with the groundwater flow velocity assumed for the Site (2 feet per day).

The column was charged with the hide-containing soil by initially filling one-fifth of the column volume with the Site groundwater. The geochemical parameters of the groundwater were maintained representative of Site characteristics (e.g., DO, pH, and ORP), typically through nitrogen purging, as needed. An equal volume of soils (one-fifth of the column volume) was passed through the top of the column and allowed to settle by gravity into the water layer to promote even settling, thereby avoiding the formation of gas pockets. This procedure was repeated until the entire length of the column was filled with the two soil types. During this filling procedure, the soil column was flushed with a stream of nitrogen to eliminate/minimize aeration of the soil. The top of the column was closed with an end cap and then sealed using plumbers putty. The column was incubated in an environmental room maintained at a temperature of 13° to 15°C. The groundwater

used to flush the column was at a pH of 6.5 and the DO was at 2.2 mg/L. To accelerate the reduction process, the influent water was de-aerated by flushing with nitrogen to reduce the DO to below 1.0.

During the first few weeks of operation, the pH of the column eluate was 6.0, the DO was less than 1.0, and the ORP was measured at +83.5 millivolts (mV). It was apparent from these initial measurements that anaerobic conditions had not become established in the test column. Furthermore, effluent from the column was extremely turbid due to the leaching of arsenic-impacted soils from the column. It was anticipated that the particulate in the effluent would interfere with the comprehensive arsenic speciation analysis; however, filtering of the eluate was considered unacceptable due to the potential for filtration to cause aeration of the samples. Thus efforts were undertaken to solve both of these operational issues.

To prevent particulate movement from the test column, approximately one-third of the arsenic-impacted soil was replaced with a clean sand, and a 2-inch layer of glass wool was placed into the effluent end of the column. The repacked column was operated as before with the DO measured below 1.0 mg/L, but the effluent still exhibited an elevated ORP at +140 mV. An initial effluent sample was collected at this point for analysis when the effluent was no longer turbid, but before the effluent showed signs of becoming chemically reduced.

Elevated ORP conditions suggested the possibility of limited microbial activity in the soils. Site samples that had been archived (at 4°C) were re-tested for pH levels, and analyzed to enumerate indigenous bacterial populations. Plate counts showed that both the arsenic-impacted soils and the hide-containing soils were high in bacteria (i.e.,  $2.5 \times 10^6$  and  $3.5 \times 10^5$  cells per gram, respectively). In addition, the hide-containing soils exhibited a very high diversity of bacterial types. A hide-containing sample was then incubated with glucose in a sealed system to verify that the indigenous bacteria (with only the indigenous nutrients) could deplete the sample's oxygen to yield low ORP conditions.

The oxygen-uptake diagnostic experiment showed that the hide-containing soil was not limited in essential nutrients, and that the indigenous bacteria could deplete all available sample oxygen. In this diagnostic experiment, vials that had been amended with distilled water, Site water, and a nutrient-rich medium all exhibited low ORP levels (i.e., -30, -80, and -135 mV, respectively), after five days of incubation. Thus, results from the diagnosis testing showed that hide-containing soils were capable of supporting microbial activity. Envirogen therefore concluded that the prior test conditions were appropriate, but that low temperature and/or an insufficient acclimation period had retarded the establishment of an anaerobic microbial population.

To overcome this limitation, the test column was incubated at a warmer temperature (21°C) for four days, and then returned to the lower incubation temperatures for the remainder of the experiment. As a result of this transient increase in incubation temperature, the test column showed the expected performance (i.e., depleted dissolved oxygen and a reduced ORP in the effluent). The column effluent was monitored for a few days to verify that performance had stabilized as indicated by maintaining low DO and ORP measurements. Only after showing this expected performance was the column effluent sampled and analyzed.

#### Arsenic Analysis

After the first week of column operation, prior to the diagnostic testing for the ORP, influent and effluent water samples were collected for analysis of the following arsenic species: arsenic III, arsenic V, monomethyl arsenate (MMA), dimethyl arsenate (DMAA), and total arsenic. After anaerobic conditions were established in the column (following the diagnostic testing and after establishing reduced conditions in the column), a second effluent sample was collected and analyzed for arsenic species.

For each sample, teflon-lined, 250-mL bottles were filled with water leaving no headspace. To prevent alterations in the geochemical parameters of these samples (e.g., DO and ORP), the water was collected in nitrogen-purged glass carboys. The downstream side of

the purged carboys was vented to an empty gas sampling bag to allow for the displacement of nitrogen from the carboy. The DO and ORP of the collected water were checked to verify that the collection of the samples did not cause sample aeration. The samples were transported for overnight delivery to Brooks Rand for analysis.

## **2.2 Work Element 2 - Downgradient Groundwater Investigation**

The downgradient groundwater investigation included evaluations of groundwater geochemistry and groundwater flow gradients in the area of the HBHA Pond, and development of a preliminary groundwater flow model for the Site and the area downgradient of the Site. The objective(s) and scope of each component of the downgradient groundwater investigation are described in detail below.

### **2.2.1 Groundwater Geochemistry**

In order to assess current geochemical conditions in downgradient groundwater, calibrate the preliminary groundwater flow model, and provide groundwater for the batch adsorption tests and biodegradation tests being performed as part of the HBHA pond sediment investigation (Work Element 3), groundwater samples were collected by Roux Associates from MicroWells™ installed by Pine & Swallow Associates, Inc. (Pine & Swallow) along the east bank of the HBHA Pond and wetlands. Locations of the MicroWell™ clusters are shown in Figure 1. MicroWell™ cluster MC-1 was installed at a point approximating the former location of GSIP monitoring well cluster OW-56, permitting comparison of SSI and GSIP data for consistency. MicroWell™ clusters MC-2 and MC-3 were installed in previously-unsampled areas.

Each MicroWell™ cluster consisted of three 1-inch-diameter, carbon-steel MicroWells,™ each with 10 feet of well screen. At each MicroWell™ cluster, one MicroWell™ screened the interval just above the bedrock surface, one was screened across or just below the water table, and one was screened approximately halfway between the water table and the bedrock surface. MicroWell™ construction details are provided in Table 1.

Following installation of the MicroWells,<sup>TM</sup> each MicroWell<sup>TM</sup> was developed to establish hydraulic connection with the surrounding aquifer and to minimize the amount of suspended sediment in the groundwater entering the MicroWells.<sup>TM</sup> Following development, groundwater samples were collected from each MicroWell<sup>TM</sup> and filtered in the field. Samples were submitted to IEA for analysis (using CLP protocols where appropriate) of COCs and the following geochemical parameters:

- DOC;
- sulfate;
- sulfide;
- major cations;
- major anions; and
- ferrous iron;

Unfiltered samples were also submitted to IEA for analyses of TOC. In addition, the groundwater samples were analyzed in the field for pH, Eh, DO, temperature, and specific conductance.

Samples of groundwater from MicroWells<sup>TM</sup> MC-1I, MC-1D, and MC-3S were also submitted to Brooks Rand for analysis of arsenic species, and to CDM's Denver, Colorado laboratory for use in batch adsorption testing of pond and wetland sediment. Groundwater from MC-1D was also sent to ES&E's Gainesville, Florida laboratory for use in biodegradation testing of pond and wetland sediment.

### **2.2.2 Groundwater Flow Gradients**

The MicroWell<sup>TM</sup> clusters were also used, in conjunction with stream gauges installed in the HBHA Pond and in the downstream wetlands at locations immediately adjacent to the MicroWell<sup>TM</sup> clusters (Figure 1), to generate water-level elevation data needed to further evaluate groundwater/surface water interactions and the direction(s) and magnitude of vertical hydraulic gradients in the immediate vicinity of the HBHA Pond and the downstream wetlands. This information was used, in turn, to calibrate the preliminary groundwater flow model.

The measuring point at each MicroWell™ and stream gauge was surveyed (using existing Site control), and water levels were measured at each MicroWell™ and stream gauge on May 1, 1997, during a period of relatively low precipitation.

### **2.2.3 Groundwater Modeling**

The overall objectives of the SSI modeling effort, being performed by CDM, are to:

- quantitatively represent the key hydrogeological and geochemical processes controlling fate and transport of COCs at the Site;
- help demonstrate the validity of the GSIP conclusions regarding COC fate and transport by reproducing existing conditions;
- project future Site conditions; and
- identify data gaps and assist the design of additional field work as needed.

The modeling work is designed to be conducted in phases as new data are collected and analyzed. The first modeling phase, which is documented in this report, entailed the development of an initial groundwater flow model. Subsequent modeling work will build on this initial model. Specific objectives of the initial flow model development included:

- investigation of flow paths and points of discharge for Site groundwater;
- testing the sensitivity of the preliminary model to hydrogeologic variables (e.g., changes in hydraulic conductivity); and
- estimation of the rate of groundwater discharge to the HBHA Pond, to help assess the assimilative capacity of the pond sediment.

The DYNFLOW modeling code, developed by CDM, was used for this study. Since 1980, DYNFLOW has been used in more than 150 groundwater modeling studies. It has been applied at a number of Superfund sites and has been accepted as evidence in litigation proceedings. The DYNFLOW code has also been reviewed and tested by the International Groundwater Modeling Center (IGWMC, 1985).

The governing equation for the three-dimensional groundwater flow that is solved by DYNFLOW is:

$$S_s \frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x_i} K_{ij} \frac{\partial \phi}{\partial x_j} ; i, j = 1, 2, 3$$

where the state variable  $\phi$  represents the potentiometric head [L];  $K_{ij}$  represents the hydraulic conductivity [ $LT^{-1}$ ] tensor;  $S_s$  is the specific storativity (volume/volume/length), [ $L^{-1}$ ];  $x_j$  is a cartesian coordinate and  $t$  is time.

DYNFLOW accepts various types of boundary conditions on the groundwater flow systems, including:

- specified head boundaries (e.g., lakes, streams or other points of known head);
- specified flux boundaries (e.g., rainfall infiltration, well pumpage, no flow streamlines);
- rising water boundaries that are hybrid boundaries (i.e., specified head or specified flux depending on system status); and
- “third type” boundaries, whereby a relationship between head and flux is defined (e.g., “general head” and river boundaries).

DYNFLOW can also simulate ponds as specified head boundaries in which a water balance on the pond is performed to track the rise and fall of pond level with changing inflow and outflow conditions in the groundwater system.

DYNFLOW uses a triangular element in plan view, which gives wide flexibility in grid variation over the area of study. Within each level of the model, an identical grid is used; but, the thickness of each model layer (vertical distance between levels in the model) can vary at each point in the grid

A description of the Site model grid, layering, construction, and calibration is provided in Section 4.3.

### **2.3 Work Element 3 - HBHA Pond Sediment Investigation**

The HBHA Pond sediment (groundwater/surface-water interface) investigation included evaluations of sediment geochemistry, adsorption capacity, and biodegradation capacity. The data generated were used to evaluate the current and long-term environmental fate of COCs as groundwater discharges to the HBHA Pond. The objective(s) and scope of each component of the HBHA Pond sediment investigation are described in detail below.

#### **2.3.1 Sediment Geochemistry**

Sediment samples were collected by Roux Associates from two locations in the HBHA Pond (Figure 1) in order to assess current geochemical conditions in pond sediment, and to provide sediment for batch adsorption testing and biodegradation testing. At sampling point SED-1, located at the northern end of the HBHA Pond, Roux Associates obtained grab samples of both the black, fine-grained ooze (i.e., detrital sediment) and the underlying sandy material (i.e., the aquifer matrix). At sampling point SED-2, located at the southern end of the pond, only a sample of the black ooze could be obtained. Each sediment sample was homogenized in the field and submitted to IEA for analysis (using CLP protocols where appropriate) of COCs and the following geochemical parameters:

- TOC;
- hexavalent chromium;
- total sulfur;
- acid volatile sulfides;
- pH; and
- Eh.

In addition, the three sediment samples collected from the HBHA Pond were also submitted to Core Laboratories, Inc. (Core Labs) of Aurora, Colorado for analysis of sulfur species. Samples of the black ooze from SED-1 were also sent to CDM's Denver, Colorado laboratory for batch adsorption testing, and to ES&E's Gainesville, Florida laboratory for biodegradation testing.

Sediment from SED-1 was also analyzed by CDM using electron microscopy (EM) to identify arsenic- and/or chromium-containing particles. The EM analyses were performed by CDM on a JEOL 8600 Superprobe located at the University of Colorado in Boulder, Colorado. X-ray fluorescence (XRF) analyses were also conducted on sample SED1 0-1.5 (black ooze) using a Spectrace TX-5000 EDXRF spectrometer located in CDM's Denver laboratory. Concentrations (mg/kg or ppm) were obtained for the following 16 elements:

- Chromium
- Arsenic
- Lead
- Mercury
- Zinc
- Calcium
- Cadmium
- Barium
- Silver
- Titanium
- Manganese
- Iron
- Copper
- Nickel
- Antimony
- Cobalt

### **2.3.2 Adsorption Capacity**

CDM conducted batch adsorption tests on the black ooze collected from SED-1 to evaluate the adsorption capacity of the pond sediment. As discussed in Section 2.2.1, groundwater collected by Roux Associates from MicroWell™ MC-1I was used to provide the highest concentrations of arsenic, chromium, benzene, and toluene. However, in order to provide high enough aqueous concentrations to saturate the sediment, it was necessary to spike MC-1I with additional chromium and arsenic.

Batch tests were performed according to the procedures outlined in "Batch-Type Procedures for Estimating Soil Adsorption of Chemicals" (U.S. EPA, 1992).

### Inorganic Parameters

Five batches for the arsenic tests and one batch for the chromium tests were prepared using 500 mL nalgene bottles. The ratio of solution to soil for each batch was held constant at 47 to 1 (mL:g).

For the arsenic tests, each of the five batches were prepared using 10-, 15-, 20-, 25-, and 30-milligram per liter (mg/L) arsenic solutions prepared using groundwater from MicroWell™ MC-1I and reagent grade  $\text{KH}_2\text{AsO}_4$ . The chromium batch was prepared separately to minimize interaction between the relatively high concentrations of chromium and arsenic used in the tests. For the chromium batch tests, groundwater from MicroWell™ MC-1I was spiked with  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ . The initial and spiked concentrations for the batches are summarized below.

Batch	Sample ID	Arsenic Concentration (mg/L)	Chromium Concentration (mg/L)
1	SED1-10	<b>10*</b>	0.03
2	SED1-15	<b>15</b>	0.03
3	SED1-20	<b>20</b>	0.03
4	SED1-25	<b>25</b>	0.03
5	SED1-30	<b>30</b>	0.03
6	SED1-Cr	Not measured	<b>3.1</b>

\*Numbers in bold represent spiked concentrations

A seventh batch containing no soil was prepared using the 25 mg/L arsenic solution (batch 4) in order to check the ICP lab analyses against the actual spiked concentrations. Chromium was also measured in these solutions in order to obtain the initial chromium concentrations in the sample from MC-1I. Based on arsenic analyses performed on samples taken from these wells by Roux Associates, the initial arsenic concentrations (0.5 mg/L) were assumed to be insignificant compared to the spiked concentrations. Therefore, no initial arsenic concentrations were measured.

All samples were agitated in a rotary tumbler for 72 hours. Following tumbling the samples were sent to Evergreen Analytical Laboratory (Evergreen) in Wheatridge, Colorado for centrifugation, filtering and analysis of arsenic and chromium.

#### Organic Parameters

Five batches were prepared in 40 mL vials using varying soil to solution ratios and constant concentrations of benzene and toluene. A summary of the soil to solution ratios used is as follows:

Batch	Soil Mass (grams)	Solution Volume (mL)	Ratio (mL/g)
1	1	41	41:1
2	2	40	20:1
3	4	39	9.8:1
4	7	34	4.9:1
5	10	32	3.2:1

Based on previous analyses conducted on groundwater from MicroWell™ MC-11 (collected by Roux Associates), no benzene spike was necessary for this test.

All batches were sealed tightly, placed in a rotary tumbler and agitated for 72 hours. Following tumbling the samples were sent to Evergreen for analysis of benzene and toluene. The samples were centrifuged prior to extraction.

#### **2.3.3 Biodegradation Capacity**

Biodegradation screening tests were performed by ES&E on a sample of HBHA Pond sediment to evaluate the potential for microflora present in the pond sediment to biodegrade benzene and toluene in groundwater discharging to the HBHA Pond. The biodegradation tests were run on a sample of the black ooze collected at SED-1 (northern end of the pond). In addition, a sample of sterilized (autoclaved) beach sand (i.e., with no organic matter) was used as an abiotic control sample, since sufficient sample volume for

an abiotic control could not be collected at SED-1. Groundwater from MicroWell™ MC-1D was used to provide a source of benzene and toluene for the biodegradation screening tests.

The two samples (SED-1 and the sand control) were thoroughly homogenized in their original containers and aliquots of each sample were removed for moisture determination and for analysis of pH and nitrate to determine if sediment conditions are optimal for maintaining microbial activity. Replicate 6-gram portions of the samples (adjusted for moisture content) were then placed in 40-mL amber glass vials, and labeled according to sample number, replicate number, and day of testing (i.e., day 0, 2, 4, 7, or 14). Each vial was then filled with 25 mL of groundwater from MC-1D (sufficient headspace was left in each vial to maintain aerobic conditions), capped, and mixed. In addition, a groundwater control sample was placed in empty (i.e., with no sediment) 40-mL vials with no headspace, and labeled for analysis on day 0 and day 14. The water in the vials labeled for analysis on day 0 were then analyzed for benzene and toluene, while the remaining vials were stored at ambient laboratory temperature for up to 14 days. Replicates of each sample were sacrificed for chemical analysis of benzene and toluene (in the overlying water) on days 2, 4, 7, and 14. In addition, the groundwater control sample was analyzed for benzene and toluene on day 14.

## **2.4 Work Element 4 - HBHA Pond Surface-Water Investigation**

The HBHA Pond surface-water investigation included an evaluation of surface-water geochemistry and a determination of the residence time of surface water within the pond. The objective(s) and scope of each component of the HBHA Pond surface-water investigation is described in detail below.

### **2.4.1 Surface-Water Geochemistry**

Surface-water samples were collected by Roux Associates from multiple horizons (i.e., shallow, intermediate, and deep) at two locations in the HBHA Pond and from a single

horizon at one location in Hall's Brook just upstream of its mouth at the HBHA Pond (Figure 1) in order to assess current geochemical conditions in pond surface water, and to evaluate the efficiency with which the pond sediment attenuate groundwater COCs as groundwater discharges upward through the pond sediment. Two surface-water samples (i.e., one filtered, one unfiltered) from each location/horizon were submitted to IEA for analysis (using CLP protocols where appropriate) of COCs and the following geochemical parameters:

- sulfate;
- sulfide;
- major cations;
- major anions; and
- ferrous iron.

One filtered sample from each location/horizon was also submitted to IEA for DOC analyses, while one unfiltered sample from each location/horizon was submitted for analyses of TOC. In addition, all surface-water samples were analyzed in the field for pH, Eh, DO, temperature, and specific conductance.

#### **2.4.2 Surface-Water Residence Time**

The residence time of surface water in the HBHA Pond was measured to evaluate how long COCs discharged from Site groundwater may potentially reside in the pond. Residence time was estimated by performing a dye study. Rhodamine dye was added to Hall's Brook just upstream of its mouth at the HBHA Pond (i.e., near surface-water sampling point SW-6, Figure 1), and a portable rhodamine dye detector was placed at the outlet of the HBHA wetland (i.e., at the Mishawum Road outfall, Figure 1) to measure the Gaussian distribution of the dye as it flowed out of the HBHA wetland and into the Aberjona River. GSIP stream-flow data (Roux Associates, 1991) were then used to determine the fraction of the total travel time (indicated by the dye) that represented retention in the HBHA Pond.

## **2.5 Work Element 5 - HBHA Wetland Investigation**

The HBHA wetland investigation included evaluations of surface-water and sediment geochemistry, the adsorption capacity and biodegradation capacity of wetland sediment, and the residence time of surface water within the wetlands. The objective(s) and scope of each component of the HBHA wetland investigation is described in detail below.

### **2.5.1 Surface-Water Geochemistry**

Surface-water samples were collected by Roux Associates from single horizons at two locations within the HBHA wetlands, and at one location in the Aberjona River just downstream of the Mishawum road culvert (Figure 1). These samples were collected and analyzed to assess current geochemical conditions in wetland surface water and to evaluate the efficiency with which the HBHA Pond and wetlands retain Site-related groundwater COCs once discharged into the pond. To accomplish this, two surface-water samples (i.e., one filtered, one unfiltered) from each location were submitted to IEA for analysis (using CLP protocols where appropriate) of COCs and the following geochemical parameters:

- sulfate;
- sulfide;
- major cations;
- major anions; and
- ferrous iron.

One filtered sample from each location was also submitted to IEA for DOC analyses, while one unfiltered sample from each location was submitted to IEA for analyses of TOC. In addition, all surface-water samples were analyzed in the field for pH, Eh, DO, temperature, and specific conductance.

### **2.5.2 Sediment Geochemistry**

One sediment core was collected by Roux Associates from each of two locations in the HBHA wetlands (Figure 1) in order to assess current geochemical conditions in wetland sediment, to assess vertical gradations in sediment geochemistry, and to provide sediment

for batch adsorption testing and biodegradation testing. Each core was 2.5 feet long, and was divided into five 0.5-foot subsamples. Each sediment subsample was homogenized in the field and submitted to IEA for analysis (using CLP protocols where appropriate) of COCs and the following geochemical parameters:

- TOC;
- hexavalent chromium;
- total sulfur;
- acid volatile sulfides;
- pH; and
- Eh.

In addition, the sediment samples collected from the HBHA wetland were also submitted to Core Labs for analysis of sulfur species. Sediment samples from SED-3 and SED-4 were also sent to CDM for batch adsorption testing, EM analysis, and XRF analysis. Fine-grained sediment (i.e., the upper 1.5 feet) from SED-4 was composited and sent to ES&E for biodegradation screening tests.

### **2.5.3 Adsorption Capacity**

CDM conducted batch adsorption tests on the fine-grained sediment from the upper 0.5 foot of sample SED-3 to evaluate the adsorption capacity of these sediment. As discussed in Section 2.2.1, groundwater collected by Roux Associates from MicroWell™ MC-3S was used to provide a source of COCs. However, in order to provide high enough aqueous concentrations to saturate the sediment, it was necessary to spike the sample from MC-3S with additional benzene, arsenic and chromium. The testing procedures employed (described in Section 2.3.2.) for the HBHA Pond sediment were otherwise the same. The initial and spiked concentrations for the batches are summarized below.

Batch	Sample ID	Arsenic Concentration (mg/L)	Chromium Concentration (mg/L)
1	SED3-10	<b>10*</b>	0.01
2	SED3-15	<b>15</b>	0.01
3	SED3-20	<b>20</b>	0.01
4	SED3-25	<b>25</b>	0.01
5	SED3-30	<b>30</b>	0.01
6	SED3-Cr	Not measured	<b>3.4</b>

\*Numbers in bold represent spiked concentrations

#### 2.5.4 Biodegradation Capacity

Biodegradation screening tests were performed by ES&E on a sample of wetland sediment to evaluate the potential for microflora present in the wetland sediment to biodegrade benzene and toluene in groundwater. The biodegradation tests were run on a sample of wetland sediment collected at SED-4 (southern end of the wetland). In addition, a second sample from SED-4 that was treated with mercuric chloride (to kill native microflora) was used as an abiotic control sample. Groundwater from MicroWell™ MC-1D was used to provide a source of benzene and toluene for the biodegradation screening tests.

The experimental design used to evaluate the biodegradation capacity of the wetland sediment was identical to that used for the HBHA Pond sediment (see Section 2.3.3).

#### 2.5.5 Surface-Water Residence Time

The residence time of surface water in the downstream wetlands (i.e., between the outlet of the HBHA Pond and the outlet of the wetlands) was estimated using the same dye study that was described in Section 2.4.2. GSIP stream-flow data (Roux Associates, 1991) were then used to determine the fraction of the total travel time (indicated by the dye) that represented retention in the downstream wetlands.

### **3.0 RESULTS OF SOURCE AREAS INVESTIGATION**

The results of the various components of the source areas investigation (i.e., groundwater geochemistry, soil geochemistry) are presented below.

#### **3.1 Groundwater Geochemistry**

As discussed in Section 2.1.1, five source-area groundwater samples were collected at the Site using a Geoprobe™ in order to assess current source-area geochemistry. The source-area samples and their associated suspected source areas are shown below.

- GW-1                      -        West Hide Pile
- GW-2                      -        Arsenic Pit
- GW-3/5                   -        East-Central Hide Pile
- GW-4                      -        South Hide Pile

Source-area groundwater geochemistry is discussed below. The discussion is separated into two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Source-areas groundwater quality data are provided in Appendix A.

##### **3.1.1 COCs**

COC concentrations in source-area groundwater are shown in Table 2 and are compared to GSIP data in Figures 2 through 5 for benzene, toluene, arsenic, and chromium, respectively.

As a whole, the SSI source-area groundwater data indicate that certain source-area COC concentrations have decreased significantly since the GSIP (c. 1990 - 1992), particularly at the East-Central hide pile and the Arsenic Pit. The concentrations and distribution of each COC are discussed separately below.

### Benzene

Out of the five source-area groundwater samples, benzene was detected only in groundwater sample GW-4, which was collected immediately downgradient of the South Hide Pile (Figure 2). Sample GW-4 was collected from a depth of 41 feet below land surface at the point where GSIP monitoring well OW-54C (screened from 40 to 45 feet below land surface) was formerly located. The detection of benzene in sample GW-4 and the concentration at which benzene was detected are both consistent with data developed at OW-54C during the GSIP and during subsequent sampling events.

The absence of benzene in groundwater samples GW-1 (West Hide Pile) and GW-3 and 5 (East-Central hide pile) is also consistent with GSIP data. However, the absence of benzene in groundwater sample GW-2 (Arsenic Pit), which was collected from a depth of 12 feet below land surface at the point where GSIP monitoring well OW-43 (screened from 4 to 14 feet below land surface) was formerly located, is not consistent with the GSIP data for monitoring well OW-43. Benzene had been detected at a concentration of 518 ug/L in OW-43 during the GSIP. This suggests that the benzene source in this area may have attenuated since the GSIP was completed in 1992, or that capping of the Site following the GSIP has reduced benzene leaching and/or mobility.

### Toluene

Toluene was detected in two of the five source-area groundwater samples: GW-3 (4 ug/L) and GW-4 (150 ug/L). The detection of toluene in sample GW-4 (South Hide Pile) and the concentration at which toluene was detected are both consistent with data developed at OW-54C during the GSIP (Figure 3). The detection of toluene in sample GW-3 (East-Central hide pile), which was collected from a depth of 23 feet below land surface near the point where GSIP monitoring well OW-16 (screened from 15 to 35 feet below land surface) was formerly located, is also consistent with historical groundwater quality data for monitoring well OW-16. However, the low concentration (4 ug/L) detected in GW-3 is not consistent with the historical groundwater quality data for monitoring well OW-16, where toluene had been detected consistently at concentrations exceeding 10,000 ug/L

ever since the initial RI was conducted at the Site in 1983. This suggests that the toluene source(s) in this area may have attenuated significantly since the GSIP was completed in 1992, or that capping of the Site following completion of the GSIP has reduced toluene leaching and/or mobility.

The absence of toluene in groundwater samples GW-1 (West Hide Pile) and GW-2 (Arsenic Pit) is consistent with GSIP data. However, the absence of toluene in groundwater sample GW-5 (East-Central hide pile), although not directly comparable to any GSIP data point (i.e., the location of GW-5 has no analogous GSIP monitoring well), is not consistent with data for GSIP monitoring well OW-39, located nearby. Toluene had been detected at 140 ug/L in OW-39 during the GSIP. The toluene detection in OW-39 during the GSIP was related to the toluene source at OW-16, which, as discussed above, appears to have attenuated significantly since the GSIP.

#### Arsenic

Arsenic was detected in all but one of the five source-area groundwater samples (Figure 4), which is consistent with GSIP groundwater quality data in that, during the GSIP, arsenic was detected downgradient of most of the areas identified as suspected source areas. The arsenic concentrations detected in samples GW-4 (South Hide Pile) and GW-5 (East-Central hide pile) were generally consistent with those detected in the respective analogue wells (OW-54C and OW-39, respectively) during the GSIP. The arsenic concentrations detected in samples GW-2 (Arsenic Pit) and GW-3 (East-Central hide pile), on the other hand, were considerably lower than the arsenic concentrations detected in the respective analogue wells (OW-43 and OW-16, respectively) during the GSIP (c. 1990 - 1992), suggesting that the arsenic sources in these areas have attenuated since the GSIP, or that mobility of the arsenic has been reduced through consumption of soluble organic compounds (SOC) and/or through reduction in leaching resulting from site capping following completion of the GSIP.

Arsenic was not detected in sample GW-1 (West Hide Pile), which is not consistent with GSIP (c. 1992) data for its analogue well, WP-5, where arsenic was detected at a concentration of 869 ug/L. This also suggests that the arsenic source in this area has attenuated, or arsenic mobility has been reduced since completion of the GSIP in 1992.

### Chromium

Chromium was also detected in all but one of the five source-area groundwater samples (Figure 5), which is consistent with GSIP groundwater quality data in that, like arsenic, chromium was also detected during the GSIP downgradient of many of the areas identified as suspected source areas. The chromium concentrations detected in samples GW-2 (Arsenic Pit), GW-4 (South Hide Pile), and GW-5 (East-Central hide pile) were generally consistent with those detected in the respective analogue wells (OW-43, OW-54C, and OW-39, respectively) during the GSIP. The chromium concentrations detected in sample GW-3 (East-Central hide pile), on the other hand, was considerably lower than the chromium concentrations detected in its respective analogue well (OW-16) during the GSIP (c. 1990 - 1992), suggesting that the chromium source in this area has attenuated since the GSIP was conducted, or that mobility of the chromium has been reduced through consumption of SOC and/or through reduction in leaching resulting from site capping following completion of the GSIP.

Chromium was not detected in sample GW-1 (West Hide Pile), which is consistent with GSIP data for its analogue well, WP-5.

### **3.1.2 Geochemical Indicator Parameters**

The breakdown of hide materials has been postulated (Roux Associates, 1991, 1992) to result in a leachate containing DOC such as proteins and amino acids, which contain amine groups. The hide pile leachate is more reducing than the Site groundwater, such that the higher the influx of leachate, the more reducing the groundwater becomes.

The source-area groundwater has Eh's ranging between -47 and 269 mV, with a median of 109 mV, and pHs from 4.1 to 7.7 with a median of 6.7. The Eh-pH conditions are consistent with a mildly reducing environment. Source area Eh's measured during the GSIP (with the exception of the final sampling round data which have been determined to be inaccurate) were all negative, ranging from -56.1 to -91.7 mV (see Table 3). These conditions were significantly more reducing than the data collected during the SSI. The species that are present in the groundwater, and the mobility of the COCs, are dependent on the Eh-pH conditions. Specifically, more arsenic and chromium are leached, and more mobile forms are produced, by water with lower Eh's.

The presence of ammonia reflects the mildly reducing conditions and the probable breakdown of organically-bound nitrogen (amines). Under more oxidizing (i.e., higher Eh) conditions, ammonia is oxidized to nitrite ( $\text{NO}_2^-$ ) and nitrate ( $\text{NO}_3^-$ ). The ammonia concentrations detected during the SSI were considerably lower than the respective concentrations detected during the GSIP (c. 1990 - 1992) in the east central (2,300 mg/L for OW-16 versus 115 mg/L in GW-5) and South Hide Piles (7,960 mg/L in OW-12 versus 1,270 mg/L in GW-4), indicating less hide pile leaching is occurring today than in the early 1990s.

The source-area groundwaters are apparently not currently reducing enough to support sulfide ( $\text{S}^{2-}$ ) species under equilibrium conditions, and no sulfide was detected in the Site groundwaters during the SSI. However, up to 120 mg/L sulfide was measured during the GSIP. The difference in sulfide between the GSIP (c. 1990 - 1992) and the current investigation may be a result of diminished quantities of organic material available for leaching.

Alkalinity values measured during the SSI ranged from 3.8 (Arsenic Pit) to 6,400 mg/L (South Hide Pile). In the West Hide Pile, Arsenic Pit, and the East-Central hide pile, the SSI alkalinity values are much lower than those measured during the GSIP (c.1990 -

1992). For example, 2,030 mg/L alkalinity was measured in sample GW-3 as part of the SSI, compared to 11,100 mg/L measured during the GSIP (see Table 3).

SSI sulfate values ranged from less than 10 mg/L to 573 mg/L, compared to a range of less than 5 mg/L to 1,780 mg/L during the GSIP (c. 1990 - 1992). In some locations, sulfate increased since the GSIP (GW-1, GW-5), while in others, sulfate decreased (GW-4). The more oxidizing conditions indicated by the SSI Eh/pH data probably cause the increased sulfate concentrations.

Overall, total and ferrous iron concentrations were higher during the GSIP (c. 1990 - 1992) than during the SSI. This is consistent with the overall less-reducing conditions observed during the SSI. During the SSI, ferrous iron ranged from <0.05 mg/L to 4.96 mg/L with a median of 2.11 mg/L. Under more oxidizing conditions, ferrous iron is oxidized to ferric iron ( $\text{Fe}^{3+}$ ) which is very insoluble and forms an iron oxyhydroxide precipitate at pHs greater than about 3. Therefore, at near neutral pH values essentially all of the dissolved iron should exist as  $\text{Fe}^{2+}$ . In some wells (such as GW-1 with only 50 percent ferrous iron), some ferric iron may be dissolved due to being complexed, probably by organic ligands.

The TOC in the site groundwaters ranged from <1 to 47.1 mg/L with a median value of 8.58 mg/L. The highest value (47.1) was measured at well GW-3, which is in the same general location as well OW-16 from the GSIP, in which TOC values of 230, 2,730, and 2,770 mg/L were measured (between 1990 and 1992). In the South Hide Pile, SSI TOC was <1 mg/L (GW-4), compared to TOC values of 160 and 29 mg/L for the GSIP analogue well (OW-12). The decrease in TOC since the GSIP suggests a decrease in the extent of hide pile leaching or the quantity of available organic matter at the hide piles since the GSIP was completed in 1992.

The changes between the SSI data and the GSIP (c. 1990 - 1992) data for each area are detailed in Table 3, while a summary of the differences are as follows:

#### East Central Hide Pile

- Lower TOC and ammonia today indicate less hide pile leaching or less available organic material than in the early 1990s.
- Lower sulfide and higher sulfate and Eh today indicate more oxidizing conditions than in the early 1990s.
- Lower TOC and the oxidizing conditions today result in lower arsenic mobility and decreased amounts of organic-complexed arsenic than in the early 1990s.

#### South Hide Pile

- Lower TOC and ammonia today suggest less hide pile leaching or less available organic material than in the early 1990s.
- Lower sulfide and ferrous iron and higher Eh today indicate more oxidizing conditions than in the early 1990s.
- Lower TOC and the oxidizing conditions today result in lower arsenic mobility and should be reflected in even lower arsenic concentrations in the future than in the early 1990s.

#### West Hide Pile/Arsenic Pit

- Lower alkalinity and pH and more oxidizing conditions today have resulted in lower arsenic and higher iron concentrations than in the early 1990s.
- Arsenic mobility is reduced today as result of lower pH and more oxidizing conditions than in the early 1990s.

#### Arsenic and Chromium Speciation

The results of the arsenic speciation of the source-area groundwaters were as follows:

Sample ID	Arsenic (V) (µg/L)	Arsenic (III) (µg/L)	Organic Arsenic (µg/L)
GW-1	0.13	0.26	0.18
GW-2	30.3	0.151	10.6
GW-3	279	136	2
GW-4	421	57.4	101
GW-5	22.7	43.1	2.5

The speciation data presented above were expressed as a percentage of the total arsenic and plotted on pie diagrams, as shown in Figure 6.

The majority of the source area arsenic was in the form of arsenate (arsenic V), with the exception of wells GW-1 and GW-5, which had higher fractions of the reduced forms of arsenic, namely arsenite (arsenic III) and organic arsenic. In general, the wells with the higher arsenic concentrations are characterized by arsenate. Because arsenate is less mobile than the more reduced forms, it may be that the lower total arsenic concentration groundwaters have undergone more attenuation that has disproportionately removed arsenate.

Where comparisons were possible, the changes in speciation from the GSIP (c. 1990 - 1992) to the SSI were consistent with the less reducing conditions and less organic carbon observed during the SSI. At OW-16 during the GSIP, the arsenic concentrations were evenly divided (30%, 36%, and 34%) among arsenic III, arsenic V and organic arsenic. At GW-3 during the SSI, arsenic concentrations were substantially lower and more arsenic V (67 %) and less organic arsenic (less than 1 percent) was present. This dramatic change in arsenic speciation was not observed at GW-4 (compared to the GSIP OW-12) but should be observed in the future as organic carbon decreases and Eh increase.

Hexavalent chromium analyses were below detection limits ( $<50 \mu\text{g/L}$ ) for all samples collected during the SSI. The only detections of chromium were in the form of trivalent chromium. The data are consistent with the Eh-pH conditions of the Site groundwater. Figure 7 is an Eh-pH diagram for chromium showing the stability fields for various chromium solid and aqueous phases. Plotted on the diagram are Eh and pH data from groundwaters in the source areas (squares), the HBHA Pond (circles), and the wetland areas (diamonds). None of the data fall within the hexavalent chromium field.

The source-area data appear to form a diagonal line across the diagram. A least squares linear regression fit to the data results in a line with a slope of -0.150 (excluding GW-2,

which had a pH of 4.1 and was considered an outlier). The theoretical slope for the iron hydroxide - ferrous iron phase boundary is -0.177. Therefore, it is likely that the source groundwaters are in equilibrium with iron hydroxide or an iron-chromium hydroxide solid-solution phase.

### 3.2 Soil Geochemistry

As discussed in Section 2.1.2, Envirogen conducted a soil/hide-material column study designed to simulate, in a controlled laboratory setting, the reducing groundwater conditions previously indicated beneath the hide piles at the Site (Roux Associates, 1991, 1992), and to evaluate how such reducing conditions impact arsenic mobilization and speciation. Results from the Envirogen column study are summarized in Table 4. Three separate water samples were analyzed for this study including: (1) an initial influent water sample, (2) an initial effluent water sample taken before onset of lowered ORP conditions in the test column, and (3) a final effluent water sample taken after the column had been operating under reduced ORP conditions. These water samples were analyzed for arsenic species including total arsenic, total inorganic arsenic, arsenic (III), arsenic (V), and two specific forms of organic arsenic, monomethyl- and dimethylarsenate. The background groundwater (i.e., site water before being introduced into the test column) contained 4.2 µg/L of total arsenic, and approximately 56% of this (2.35 µg/L) was inorganic arsenic in the form of arsenic V and the remainder (44%) was in the form of an uncharacterized organic complex. This observation corresponds well to the analysis of past site samples that have shown there is a significant organic arsenic component in the groundwaters. Monomethylarsenate was detected in the background sample at 0.01 µg/L, which was near the detection limit for the analytical method used.

An initial effluent sample from the test column was collected when the eluate was free of suspended particulates. However, this effluent was analyzed for arsenic concentration and speciation before reducing conditions were established in the column, thus these data are considered to be representative of hide pile conditions in the absence of highly reducing

conditions. This initial effluent was measured to have dissolved oxygen levels at <1.0 mg/L and an ORP of +83.5 mV. Total arsenic in the initial effluent was measured at 473 ug/L. Approximately 81% of the arsenic leaching from the column (383 ug/L) was in the form of inorganic arsenic and this was primarily in the form of reduced arsenic III. In this initial effluent neither monomethyl nor dimethyl arsenate was detected (at detection limits below 1.6 ug/L). The remaining 19% of the mobile arsenic was present as an uncharacterized organic complex. Again, this observation corresponds well to the samples at the site which suggest there is likely organic arsenic present.

After establishing highly reduced conditions in the column (representative of expected system behavior in the presence of readily available SOC), the effluent exhibited an ORP of -86 mV and the dissolved oxygen was undetectable at less than 1 mg/L. The amount of arsenic leaching from the anaerobic column increased to 2,162 µg/L under these conditions, which is comparable to the 2- to 3-mg/L range observed historically at the site. There was no evidence that either monomethyl or dimethyl arsenic species were being produced in this column (at the 1.6 ug/l detection limit) which again suggests that other forms of organic arsenic are present. Of the arsenic eluting under anaerobic conditions, only 37% (805 µg/L) was in the form of inorganic arsenic, with two-thirds of this present as arsenic III and one-third present as arsenic V. Approximately 63% of the leached arsenic (1,357 µg/L) was in the form of an uncharacterized but likely organic complex.

Thus it appears that the reduced anaerobic conditions significantly increase the extent of arsenic leaching from the test columns by more than quadrupling the amount of mobile arsenic when compared to elevated redox conditions. It is significant that the extent of arsenic mobility mimics the historical observations at the site to show that the expected concentration of mobile arsenic would have been in the range of 2 to 3 mg/L. Thus the following general conclusions can be made regarding the laboratory study:

- conditions that resulted in the release of mobile arsenic were successfully recreated in this experiment;
- arsenic was released at concentrations of 2 to 3 mg/L (which is the same range as observed in the past at the site), again suggesting the success of the study in mimicking Site conditions in the past;
- the majority of the arsenic release (87.7 %) was in the form of reduced arsenic III or in the form of an organically-complexed arsenic species; and
- as reducing conditions are lessened (e.g., through utilization of the soluble organic carbon available in the hides) arsenic mobilization will be expected to be significantly reduced.

## **4.0 DOWNGRADIENT GROUNDWATER**

The results of the various components of the downgradient groundwater investigation (i.e., groundwater geochemistry, flow gradients, modeling) are presented below.

### **4.1 Groundwater Geochemistry**

As discussed in Section 2.2.1, three MicroWell™ clusters were installed adjacent to the HBHA Pond and wetlands to evaluate downgradient groundwater conditions. Well locations are shown in Figure 1. Downgradient groundwater geochemistry is discussed below. The discussion is separated into two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Downgradient groundwater quality data are provided in Appendix A.

#### **4.1.1 COCs**

COC concentrations in downgradient groundwater are shown in Table 2, and are compared to GSIP data in Figures 2 through 5.

As a whole, the downgradient groundwater quality data are consistent with the data developed during the GSIP, and indicate that COC concentrations and distribution downgradient of the Site have not changed significantly since the GSIP. The concentrations and distribution of each COC are discussed separately below.

#### **Benzene**

Benzene was detected in all three MicroWells™ at the MC-1 cluster, located near the northern end of the HBHA Pond (Figure 2). The highest benzene concentration (14,000 ug/L) was detected in the deep MicroWell™, screened just above the bedrock surface (approximately 45 feet below land surface), while concentrations of 160 ug/L were detected in both the shallow (i.e., water table) and intermediate MicroWells™ at the MC-1 cluster. These findings are consistent with data developed during the GSIP and

subsequent sampling rounds for the OW-56 monitoring-well cluster, which was formerly located where the MC-1 cluster was installed.

Benzene was not detected in any of the MicroWells™ in the MC-2 and MC-3 clusters, located further downgradient along the HBHA Pond and wetlands (Figure 1). The absence of benzene in these MicroWells™ is consistent with the GSIP data, which indicated that the benzene plume was discharging into the northern end of the HBHA Pond and did not extend south of the pond.

#### Toluene

Toluene was detected only in the deep MicroWell™ (MC-1D) at the MC-1 cluster, at a concentration of 420 ug/L (Figure 3). The detection of toluene only in the deep part of the aquifer near the northern end of the HBHA Pond, and the concentration at which it was detected, are both consistent with GSIP data.

#### Arsenic

Arsenic was detected in the shallow and intermediate MicroWells™ at the MC-1 and MC-2 clusters (located adjacent to the north and south ends of the HBHA Pond, respectively), and in the shallow MicroWell™ at the MC-3 cluster (located adjacent to the downstream wetlands). As shown in Figure 4, no arsenic was detected in any of the deep MicroWells™. (It is noted that arsenic was detected in a sample from MC-1D during arsenic-speciation analyses.) These findings are generally consistent with the GSIP data, with two minor exceptions. First, the maximum arsenic concentration detected during the SSI (547 ug/L) was in the intermediate MicroWell™ at the MC-1 cluster, whereas during the GSIP, the maximum arsenic concentration (528 ug/L) had been detected in the shallow monitoring well at the OW-56 cluster; and no arsenic had been detected in the intermediate well at the OW-56 cluster. Secondly, the detection of arsenic in the shallow MicroWell™ at the MC-3 cluster at a concentration of 164 ug/L is not consistent with GSIP data, as arsenic had not been detected at concentration greater 50ug/L anywhere

south of the HBHA Pond (Figure 4). The detection of arsenic south of the HBHA Pond is likely attributable to a separate, downgradient arsenic source, including possibly desorption of arsenic from adjacent arsenic-containing wetland sediment.

#### Chromium

Chromium was detected in all three MicroWells™ at the MC-1 cluster (northern end of the HBHA Pond), as well as in the shallow MicroWell™ at the MC-3 cluster (south of the HBHA Pond). As shown in Figure 5, the detection of chromium in all three MicroWells™ at the MC-1 cluster is consistent with the GSIP data for the OW-56 cluster, as are the concentrations at which chromium was detected in the MicroWells™. However, during the SSI, the maximum chromium concentration was detected in the deep MicroWell™, whereas during the GSIP, the maximum chromium concentration was detected in the intermediate well.

The detection of chromium at MC-3S (estimated concentration of 1.6 ug/L) is consistent with GSIP data, which indicated that chromium was present at low levels in downgradient groundwater southeast of the HBHA Pond.

#### **4.1.2 Geochemical Indicator Parameters**

The SSI data indicate near-neutral pH conditions in downgradient groundwater, and Eh values from 99 to 288 mV. The pH values are similar to those obtained in the GSIP, while the Eh values are significantly more oxidizing. For instance, SSI MicroWell™ MC-1 had Eh values of 99, 210, and 173 for the shallow, intermediate and deep wells respectively, while GSIP well OW-17 had Ehs of -85, -25.3, -89.6 and 110 mV depending on the sampling date. The more oxidizing conditions of the downgradient groundwater probably reflect the decrease in soluble organic material or hide pile leaching observed at the sources.

The groundwater at MC-3 has similar Eh values as the HBHA Pond area groundwaters, with Ehs of 133, 140, and 163 mV for the shallow, intermediate and deep wells, respectively. Arsenic and iron were also higher in the SSI than in the GSIP. Well MC-3S had an arsenic value of 164 µg/L compared to a high of 4.3 µg/L for GSIP well OW-33A. The total iron in well MC-3 was 11.1, 9.04, and 10.4 mg/L for the shallow, intermediate and deep wells, respectively. This compares to values of 0.048 and 0.031 mg/L for GSIP well OW-33A. Either the wetland groundwaters have become more reducing with subsequent increased mobility of arsenic and iron over time, or the two well locations (MC-3 and OW-33A) are too far apart to be comparable.

#### Arsenic and Chromium Speciation

The results of the arsenic speciation of the downgradient groundwater were as follows:

Sample ID	Type	Arsenic (V) (µg/L)	Arsenic (III) (µg/L)	Organic Arsenic (µg/L)
MC-1I	HBHA Pond	470	51.6	(31)*
MC-1D	HBHA Pond	4.41	1.04	18.85
MC-3S	Wetland	31.6	93.4	61

\*indicates negative value obtained because total arsenic was less than inorganic arsenic

The speciation data presented above were expressed as a percentage of the total arsenic and plotted on pie diagrams, as shown in Figure 6.

MicroWell™ cluster MC-1 had 90 percent arsenate in the intermediate depth well, compared to only 18 percent in the deep well. The total arsenic in the deep well was only 24 µg/L compared to 491 µg/L in the intermediate well. The high salinity and organic content of the deep well (DOC is 936 mg/L in the deep well compared to 59.6 mg/L in the intermediate well and 14.6 in the shallow well) suggests that the deep water originated from the hide piles, but that arsenic was attenuated due to transport through the aquifer.

MicroWell™ MC-3S, which was completed just below the water table, had only 17 percent arsenate, and 83 percent reduced forms (50 percent arsenite and 33 percent organic arsenic). The reduced form of arsenic probably reflects the high organic content of the wetland, and, together with the results of the groundwater modeling, suggests that the source of the arsenic in the wetland may be desorption from sediment.

The downgradient MicroWells™ in the vicinity of the HBHA Pond are represented on the chromium Eh-pH diagram (Figure 7) by circles. Like the source area groundwater, all of the data plot within the trivalent chromium field. The data appear to line up along the vertical  $\text{Cr}(\text{OH})_3$  solid and aqueous  $\text{Cr}(\text{OH})^{2+}$  field boundary. The data to the right of the vertical field boundary in Figure 7 are either supersaturated with respect to chromium hydroxide, or these waters contain a complex that is solubilizing and mobilizing chromium. Additional evidence for an aqueous chromium complex will be presented in the batch study section.

#### **4.2 Groundwater Flow Gradients**

As discussed in Section 2.2.2, water-level elevation data needed to further evaluate groundwater/surface water interactions and the direction(s) and magnitude of vertical hydraulic gradients in the immediate vicinity of the HBHA Pond and the downstream wetlands were collected from MicroWells™ installed adjacent to the pond and wetlands. Water-level measurements were taken on May 1, 1997, during a period of relatively low precipitation.

The water-level data developed for the three MicroWell™ clusters and the adjacent stream gauges are provided in Table 5. As shown by these data, groundwater elevations at all three MicroWell™ clusters increase with depth of the wells (except between MicroWells™ MC-1I and MC-1D), indicating that groundwater flow gradients are upward at all three locations. These data are consistent with and support the GSIP conclusion that vertical groundwater flow gradients are upward beneath the HBHA Pond.

### 4.3 Groundwater Modeling

As discussed in Section 2.2.3, CDM began the initial development of a groundwater hydrogeochemical model in order to:

- investigate flow paths and points of discharge for Site groundwater;
- test the sensitivity of the preliminary model to hydrogeologic variables (e.g., changes in hydraulic conductivity); and
- estimate the rate of groundwater discharge to the HBHA Pond, to help assess the assimilative capacity of the pond sediment.

#### 4.3.1 Model Construction

The model area, shown in Figure 8, coincides with the extent of the buried valley aquifer delineated in the Oxygen Injection Demonstration Work Plan (Roux Associates, 1995). The southern model boundary is just north of Route 128, following a line of monitoring well locations.

The finite element computational grid is shown in Figure 9. In plan view, the computational grid includes 2,772 triangular elements and 1,553 nodes located at the vertices of the triangles. Layer elevations, heads and fluxes are assigned or computed at node points. Aquifer hydraulic properties are assigned to elements. Vertically, the model is divided into six computational layers, defined by seven levels of nodes placed at the layer boundary elevations at each plan view node location. In three-dimensions, the total number of computational nodes is therefore 19,404 ( $2,772 \times 7$ ).

Stratigraphically, the model incorporates the outwash deposits of the buried valley aquifer, and also the upper 25 feet of bedrock underlying the outwash. A typical model cross section is shown in Figure 10. Hydraulically, flow in the bedrock is minor compared with flow in the outwash. Nevertheless, the upper portion of the bedrock is included in the model so that any potential solute transport in the bedrock may be simulated. The bedrock and outwash formations are each subdivided into multiple computational layers to

refine the simulation of groundwater flow paths. Additionally, a discrete layer of HBHA Pond sediment was defined for some of the sensitivity simulations.

Base case hydraulic conductivities of 75 feet/day (horizontal) and 3.75 feet/day (vertical) were assigned to the outwash. These values were based on aquifer test results reported in the GSIP Phase 1 RI Final Report (Roux Associates, 1991) and model calibration. A horizontal hydraulic conductivity of 0.5 feet/day was assigned to the bedrock based on aquifer test results reported by other investigations in the region (Cherry, 1989; GeoEnvironmental Consultants, 1983). A bedrock vertical hydraulic conductivity of 0.05 feet/day was assigned.

The elevation of the bottom of the outwash (top of bedrock) was specified as presented in the Oxygen Injection Demonstration Work Plan (Roux Associates, 1995). In the southern portion of the model area, beyond the area contoured by Roux Associates (1995) the bottom of outwash was defined based on regional bedrock contours developed by Ecology and Environment (1982). Contours of the model top of bedrock/bottom of outwash are shown in Figure 11.

A uniform rate of recharge from precipitation equal to 17.5 inches/year was applied to the model area. Additional recharge was specified at the model boundaries to represent inflow to the Buried Valley Aquifer from adjacent uplands. The rate of model boundary recharge was estimated based on the area directly tributary to boundaries, multiplied by 8.75 inches/year. Figure 12 shows the estimated watershed for the model area, and also the portion of the watershed which topographic mapping indicates is directly tributary to the model boundary, distinguished from the area which is tributary to a stream which runs through the model area.

Model discharge was computed at streams, the HBHA Pond and the downgradient (southern) boundary of the model. Specified heads were assigned based on water level and topographic data to the top model level of nodes located along streams and the

HBHA Pond. Along the southern model boundary, specified heads were assigned to all model levels based on measured water levels in nearby monitoring wells. No well pumping, or other specified discharge was assigned.

#### **4.3.2 Initial Calibration and Parameter Sensitivity**

Model simulated heads using a range of specified hydraulic conductivity and recharge values were compared with measured heads at monitoring wells. Two measured head distributions were targeted:

- average measured values at site monitoring wells for the 1990-1992 period, the most recent available data for these wells; and
- heads measured in 1997 at the three newly installed micro-well clusters adjacent to the HBHA Pond and downstream wetland.

Simulated base case water-table elevations are shown in Figure 13. The base case refers to the model with specified hydraulic conductivity and recharge values listed above. Figure 14 shows a comparison of simulated and measured 1990-1992 heads for the base case. The agreement between measured and simulated heads is generally satisfactory, with a mean difference of 0.36 feet and standard deviation of 1.24 feet. Figure 15 shows the difference between simulated and measured heads at the new micro-well clusters for the base case. Again, agreement between simulated and measured heads is reasonable. In particular, the upward vertical gradient at the clusters is reasonably well represented.

A number of additional calibration simulations were made to test the sensitivity of model results to changes in specified parameters. The sensitivity simulations incorporated:

- changes in specified horizontal and vertical hydraulic conductivity of the outwash;
- changes in the specified recharge rate;

- application of a low specified hydraulic conductivity to the sediment ( $K_v = 0.1$  feet/day) at the base of HBHA Pond; and
- a change in the specified bedrock configuration and extent of the model east of the HBHA Pond.

Figure 16 shows the model grid used for the revised bedrock/revised model extent sensitivity case. In this case, the outwash aquifer is assumed to be continuous along the east side of the model area, with no intrusion of bedrock/till as incorporated in the base case model which uses the bedrock and aquifer delineation presented in the Oxygen Injection Demonstration Work Plan (Roux Associates, 1995). For the sensitivity case, the regional bedrock elevation contours developed by Ecology and Environment were applied. The regional contours indicate a wider buried valley than the bedrock contours developed for the site. The main objective of this sensitivity simulation was to see if the assumed aquifer/bedrock configuration had a significant effect on simulated flow paths.

Calibration statistics for the sensitivity simulations are summarized in Tables 6 and 7. It can be seen that none of the parameter changes had a major, site-wide effect on simulated water levels. For the 1991-1992 water levels, the mean difference was increased to 0.33 by specifying low conductivity pond sediment, and was decreased to -0.93 by the deepened drainway with ineffective lining. Changes in the specified hydraulic conductivity of the outwash aquifer and changes in recharge rate had a lesser impact on simulated water levels. Furthermore, if both hydraulic conductivity and recharge are increased by the same proportion, or decreased proportionally, simulated heads equivalent to the base case result.

Table 8 lists measured and simulated heads at the new MicroWell™ clusters for selected sensitivity simulations. Table 8 shows that simulated heads at MicroWell™ clusters 1 and 2, which are adjacent to the HBHA Pond, increase relatively significantly above measured levels when low conductivity pond sediment are specified. This is also indicated in Table 7. This result indicates that such a low hydraulic conductivity is probably unrealistic for the pond sediment. Specifying vertical conductivity for the pond sediment equal to the

vertical conductivity of the outwash aquifer provides a reasonable representation of the nearby measured head distribution.

#### **4.3.3 Simulated Discharge Fluxes**

Simulated groundwater discharge is primarily to the Aberjona River, Halls Brook including the HBHA Pond, and local tributary streams. There is also simulated discharge across the southern model boundary. As shown in Table 9, discharge across the southern boundary is less than 10 percent of total simulated discharge. Simulated groundwater discharge to the HBHA Pond is also shown in Table 9. Excepting the low conductivity pond sediment simulation which did not represent measured heads near the pond well, the range of simulated flows is from 18,300 cubic feet per day (cfd) to 35,700 cfd. This compares with an estimated rate of 41,500 cfd reported in the GSIP Phase 2 report (Roux Associates, 1992) for October 4, 1991. The October 1991 period was somewhat wetter than average, as indicated by historic streamflow measurements in the Aberjona River (USGS 1990, 1991, 1992).

Table 10 lists measured and simulated flows at surface water measurement points for October 4, 1991. The location of the surface water measuring points are shown in Figure 17. Simulated flows range from 18 to 59 percent of measured flows. This is consistent with a model area approximately half the total watershed area and measurements taken during a wetter than average period.

#### **4.3.4 Simulated Flow Paths**

Figures 18 to 24 show simulated groundwater flow paths. Flow vectors, particle tracks and particle clouds are used to depict the flow paths.

Figure 18 shows vector arrows indicating simulated flow direction in the uppermost model layer for the base case. The degree to which the flow is directed towards surface water features is evident in this figure. Flow vectors for other model layers are very similar.

Figure 19 shows simulated particle tracks started at suspected source areas. Each particle track indicates the mean simulated flow path through the aquifer from a given starting point. The results indicate flow towards, and discharge to the north end of the HBHA Pond from all of the starting locations except the West Hide Pile. Simulated flow from the West Hide Pile discharges to the New Boston Street Drainway, a tributary of Hall's Brook and the HBHA Pond.

Simulated particle tracks for the sensitivity simulations incorporating varied hydraulic conductivity of the outwash aquifer or varied recharge rate are essentially the same as shown in Figure 19 for the base case. Figure 20 shows that with pond sediment specified with an unrealistically low hydraulic conductivity, based on comparison of simulated and measured heads near the pond, discharge from the South and East-Central Hide Pile areas is to the HBHA Pond, or to Hall's Brook where it discharges to the pond.

Simulated flow vectors and particle tracks for the revised bedrock sensitivity simulation are shown in Figures 21 and 22 respectively. In this simulation, flow paths from the East Central Hide Pile area trend somewhat further south compared with the base case, but discharge is still to HBHA Pond.

Figure 23 shows a cloud of simulated particles started at different times from the East Central Hide Pile area. The trajectory of the particles includes dispersion with a longitudinal dispersivity of 30 feet and a lateral dispersivity of 3 feet, as well as advection with the base case mean groundwater flow path. The particle cloud is therefore representative of a solute plume starting in the vicinity of the East Central Hide Pile. Simulated discharge of these particles is to the north end of HBHA Pond. The same simulated particle cloud is shown in cross section in Figure 24.

#### **4.3.5 Transient Simulation of Recharge From Streams/Pond**

Normally, groundwater discharges to streams and ponds at this site. However, the streams and pond may temporarily recharge the groundwater during and after a period of

increased rainfall. This is because surface water levels respond more quickly to rainfall than groundwater levels. Such a condition was simulated to estimate transport distances into the aquifer which could result due to recharge from streams and ponds.

The initial condition for this simulation was defined by the base case steady state simulation. Simulated stream and pond levels were then raised instantaneously by 2 feet. Groundwater flow was simulated in transient mode for 60 days following the increase in surface water levels. The groundwater recharge was doubled during the transient simulation to represent wet conditions.

During the simulation, groundwater levels rose in response to the increased stream/pond levels. For a period less than 30 days, groundwater recharge from surface water continued. After that, groundwater levels had increased sufficiently that groundwater again discharged to surface water (Figure 25). During the simulation the maximum transport distance of water recharged from the HBHA Pond was less than 10 feet before flow returned back towards the pond. It is therefore considered unlikely that significant aquifer contamination can result from transient recharge of pond or water back to the aquifer.

#### **4.3.6 Initial Modeling Conclusions**

The following conclusions may be drawn from the initial groundwater modeling efforts described above:

- for all simulation cases, Site groundwater discharges to the HBHA Pond or to the New Boston Street Drainway ( a tributary of Hall's Brook and the HBHA Pond);
- simulated groundwater flow paths are not sensitive to changes in model hydraulic parameters (K and recharge);
- simulated groundwater flow paths are somewhat sensitive to assumed bedrock configuration, but points of discharge are not significantly changed;

- HBHA Pond sediment will not likely act as a significant hydraulic barrier to groundwater discharge to the pond; and
- transient recharge of pond or wetland water would be unlikely to result in any significant recontamination of the aquifer.

The first four conclusions are significant in that they support the GSIP conclusion that the COC plumes discharge to the HBHA Pond, and do not underflow or circumvent the pond. Thus, they also support the conclusion that the arsenic concentration detected at MicroWell™ cluster MC-3 does not appear to be attributed to a source at the Site. The last conclusion is also significant in that it indicates that the arsenic detected at the MC-3 cluster does not appear to be attributable to transient recharge of pond or wetland water back to the aquifer.

## 5.0 HBHA POND SEDIMENT

The results of the various components of the HBHA Pond sediment investigation (i.e., sediment geochemistry, adsorption capacity and biodegradation capacity) are presented below. These results were used to project the long-term attenuation capacity of the HBHA Pond sediment.

### 5.1 Sediment Geochemistry

As discussed in Section 2.3.1, sediment samples were collected from two locations in the HBHA Pond, (Figure 1) in order to assess current geochemical conditions in pond sediment. Two samples (black ooze and underlying sand) were collected from the northern end of the pond, while only a sample of the black ooze was obtained from the southern end of the pond. Sediment geochemistry is discussed below, with the discussion being separated into two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Sediment-quality data are provided in Appendix B.

#### 5.1.1 COCs

COC concentrations in HBHA Pond sediment are shown in Table 11 and in Figures 26 through 31. As a whole, the SSI pond sediment data appear to be generally consistent with GSIP data, indicating that COC concentrations and distribution in the pond sediment have not changed significantly since the GSIP. The concentrations and distribution of each COC are discussed separately below.

##### Benzene

Benzene was detected in all three sediment samples collected from the base of the HBHA Pond (Figures 26 and 27). The highest benzene concentration (4,100 micrograms per kilogram [ug/kg]) was detected in the sample of the black ooze collected in the northern end of the pond (i.e., SED-1, 0-1.5 ft.), where the benzene groundwater plume discharges. An order-of-magnitude difference in benzene concentrations was observed between the

black ooze samples collected in the northern and southern ends of the pond, and a two-order-of-magnitude decrease in benzene concentration was observed between the black ooze and the underlying sandy sediment (aquifer matrix) in the northern end of the pond.

These findings are all consistent with GSIP data, as shown in Figures 26 and 27.

#### Toluene

Toluene was detected at low concentrations (2 and 14 ug/kg, respectively) in the deeper, sandy sample (aquifer matrix) collected from the northern end of the HBHA Pond (SED-1, 1.5 - 2.5 ft.) and in the sample of the black ooze collected in the southern end of the pond (SED-2, 0 - 1.5 ft.). Toluene was not detected in the sample of the black ooze collected from the northern end of the HBHA Pond (SED-1, 0 - 1.5 ft.).

The presence of toluene in HBHA Pond sediment, albeit at very low concentrations, is not consistent with GSIP data. No toluene was detected in the pond sediment during the GSIP (Figure 26).

#### Arsenic

Arsenic was detected in all three sediment samples collected from the base of the HBHA Pond (Figures 28 and 29). The highest arsenic concentration (1,390 milligrams per kilogram [mg/kg]) was detected in the sample of the black ooze collected in the northern end of the pond (SED-1, 0 - 1.5 ft.), although the arsenic concentration in the black ooze at the southern end of the pond (1,270 mg/kg) was not significantly lower. An almost two-order-of-magnitude difference in arsenic concentrations was observed, however, between the black ooze and the underlying sandy sediment (aquifer matrix) in the northern end of the pond.

The detection of arsenic in the sediment at the base of the HBHA Pond and the almost two-order-of-magnitude difference in concentrations detected in the black ooze and underlying sand (aquifer matrix) in the northern end of the pond are consistent with GSIP

data (Figure 28 and 29). The similarity between the arsenic concentrations detected in the northern and southern ends of the pond during the SSI is consistent with the GSIP Phase 2 RI data (Figure 29), but not with the GSIP Phase 1 RI data, which indicated that arsenic concentrations in the northern end of the pond were considerably greater than those in the southern end of the pond (Figure 28).

### Chromium

Chromium was detected in all three sediment samples collected from the base of the HBHA Pond (Figures 30 and 31). The highest chromium concentration (1,060 mg/kg) was detected in the sample of the black ooze collected in the northern end of the pond (SED-1, 0 - 1.5 ft.), although the chromium concentration in the black ooze at the southern end of the pond (711 mg/kg) was not significantly lower. An almost two-order-of-magnitude difference in chromium concentrations was observed, however, between the black ooze and the underlying sandy sediment (aquifer matrix) in the northern end of the pond.

These findings are all consistent with GSIP data (Figures 30 and 31).

### **5.1.2 Geochemical Indicator Parameters**

A summary of the results of the X-ray fluorescence analyses on sample SED1- 0-1.5 follows:

Parameter	Concentration (mg/kg)
Arsenic	1,352
Chromium	546
Iron	143,550

The complete analysis of the 16-element XRF analyses can be found in Appendix C. As discussed in the previous section, laboratory concentrations measured by CLP methods were 1,340 and 1,060 mg/lg for arsenic and chromium, respectively. Comparison of these

data with the XRF results suggests that chromium may not be uniformly distributed within the sample. Prior to the batch tests and XRF analyses, samples were further homogenized to obtain representative samples. Typically, homogenization does not occur in the analytical laboratories. Given the heterogeneous nature of soils and the small samples (less than one gram) used by the laboratories, differences in metal concentrations are typically observed. The XRF results will be used to calculate adsorption isotherms.

The forms of sulfur in the sediment samples were as follows:

Sample ID	Pyritic (mg/kg)	Organic (mg/kg)	Sulfate (mg/kg)	Total (mg/kg)
SED1 0-1.5	0.1	4.73	0.39	5.22
SED1 1.5-2.5	0.01	0.07	0.01	0.08
SED2 0-1.5	0.24	3.41	0.23	3.88

The most abundant form of sulfur is organically bound, followed by pyritic. The total sulfur and organically bound sulfur are higher in the surface samples (black ooze) than at depth (sand), and are also higher at the HBHA pond than in the wetland (see Section 7.2.2). The sulfur forms reflect the conditions of the environment (e.g., organic-rich ooze) more so than the initial source of the sulfur. For instance, the sulfur in the HBHA pond area could have originated as sulfate or sulfide, but was later altered to other forms.

### 5.1.3 Electron Microscopy

The arsenic occurred in two forms; adsorbed onto the surfaces of iron containing minerals, such as biotite mica and pyroxene grains, and either adsorbed onto or coprecipitated with iron containing sulfate precipitates. No examples of arsenic-bearing grains were found that did not also contain iron. An example of both arsenic associations is shown in photomicrograph 1 (see Appendix D). The biotite grains, which are identified by their composition and platy habit, contained about 0.2 percent arsenic, while the iron sulfate contained 6.4 percent arsenic. Photomicrograph 2 is a "dot map" of the same frame shown in photomicrograph 1, which shows the arsenic concentration represented by

white dots. The higher the arsenic concentration, the higher the density of the dots. The mass of dots in the upper left corner of the frame is the iron sulfate grain, while the lighter accumulations of dots represent the biotite grains. Photomicrographs 3 and 4 show iron sulfates with about 2 percent arsenic. The iron sulfates may have formed prior to the arsenic entering the system, in which case the arsenic would have been adsorbed; or alternatively, the arsenic and iron sulfates may have precipitated at the same time.

Based on experiments conducted by Pierce and Moore (1982) in which arsenate was adsorbed onto a pure iron hydroxide, the maximum concentration of arsenic that can be adsorbed is about 3.4 percent. As will be discussed in the batch study section, adsorption capacity has been shown to be proportional to the iron percentage of the material. Considering that the iron sulfate is not pure, and that pure iron sulfate only contains about 37 percent iron compared to 53 percent for  $\text{Fe}(\text{OH})_3$ , the adsorption capacity would be expected to be at least 30 percent less ( $37 \text{ percent} / 53 \text{ percent} = 0.7$ ) than for a pure iron hydroxide. Therefore, the maximum arsenic concentration adsorbed onto an iron sulfate would be about 2.35 percent ( $3.4 \text{ percent} * 0.7 = 2.35 \text{ percent}$ ). In order to have an iron sulfate containing in excess of 2.35 percent (such as the grain shown in photomicrograph 1), at least some of the arsenic must have been coprecipitated with the iron sulfate.

Chromium was present in the sample, but it could not be located during the EM scan. Apparently, the chromium distribution was not uniform, and the one gram EM sample represented a low chromium portion of the bulk sample.

The results of the EM analyses (e.g., grain counts, analytical results, etc.) are provided in the data sheets provided in Appendix D.

## 5.2 Adsorption Capacity

As discussed in Section 2.3.2, CDM conducted batch adsorption tests to evaluate the adsorption capacity of the HBHA Pond sediment. The results of the tests for each of the COCs is presented separately below.

### Arsenic

The results of the batch adsorption study for arsenic were as follows:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Initial Soil* Concentration (mg/kg)	Final Soil Concentration (mg/kg)
SED1-10	10	469	10	0.3	1,352	1,804
SED1-15	10	474	15	0.23	1,352	2,051
SED1-20	10	474	20	0.57	1,352	2,280
SED1-25	10	471	25	0.54	1,352	2,508
SED1-30	10	472	30	0.71	1,352	2,726

\* Measured by XRF by CDM

Final soil concentrations (x/m) were calculated by mass balance using the following equation:

$$\frac{x}{m} = \frac{(C_{\text{soil}_i} * M_{\text{soil}} + C_{\text{soln}_i} * V_{\text{soln}}) - (C_{\text{soln}_E} * V_{\text{soln}})}{M_{\text{Soil}}}$$

Where:

$C_{\text{soil}_i}$  =The concentration of the COC in the soil initially

$M_{\text{soil}}$  =The mass of soil used in the batch

$C_{\text{soln}_i}$  =The initial (spiked) concentration of arsenic or chromium in the solution

$V_{\text{soln}}$  =The volume of solution used in the batch

$C_{\text{soln}_E}$  =The concentration of the COC in the solution at equilibrium

As shown in the above calculation, batch studies include all mechanisms of arsenic removal. Even though the term “adsorption” is used, all removal mechanisms including adsorption, precipitation, and coprecipitation are quantified, and the calculated capacity should be viewed as a combination of all removal mechanisms. However, a batch study is a closed system, unlike the real system where aqueous components can be replenished. For instance, in the batch study, once all of the dissolved iron and sulfate has been precipitated, coprecipitation of arsenic will no longer occur. In the real system, where the iron and sulfate can be replenished, coprecipitation may continue indefinitely, assuming the environmental conditions remain favorable.

When the final (equilibrium) solution concentration is plotted against the final (equilibrium) soil concentration a diagram called an isotherm results. The data conform to the Langmuir Adsorption Model, which is represented by the following equation:

$$\frac{x}{m} = \frac{(K_L + A_M) * C}{1 + K_L * A_M}$$

Where

$x/m$  = The equilibrium soil arsenic concentration in mg/kg

$C$  = The equilibrium solution arsenic concentration in mg/L

$K_L$  = The Langmuir adsorption constant in mg/L

$A_M$  = The maximum arsenic adsorption capacity of the solid in mg/kg

Langmuir isotherms are based on the assumption that there are a finite number of adsorption sites, resulting in a maximum adsorption that is possible on the sorbent surface. This is represented on the isotherm by the adsorption curve becoming more “flat”. Curves will fit through the actual data by varying the constants until the best visual match is observed.

When the HBHA pond sediment data are fitted to the Langmuir model as shown in Figure 32, an  $A_M$  of 3,350 mg/kg and a  $K_L$  of 5 mg/L is obtained. Note that as the maximum adsorption capacity of the soil ( $A_M$ ) is approached (i.e., where the curve begins to flatten out), the partitioning of arsenic into solution increases relative to the soil concentration. Once  $A_M$  is reached, all of the available adsorption sites for arsenic are saturated (i.e., filled), and any additional arsenic added to the system will not be adsorbed, resulting in increased concentrations in the solution.

The results obtained are consistent with the findings of Pierce and Moore (1982), who calculated a  $K_L$  of 0.065 mg/L and an  $A_M$  of 34,014 mg/kg for arsenate adsorption at pH 7 onto pure iron hydroxide. As previously discussed (Section 5.1.3), the EM results indicate that arsenic adsorption onto the pond sediment is limited to iron-bearing minerals. Because the pond sediment is also composed of many non iron-bearing sediment, they would be expected to have lower adsorption capacities than a pure iron hydroxide adsorbent. Livesey and Huang (1981) found that the arsenate adsorption capacity of a sediment is proportional to the iron concentration of the sediment. Figure 33 is a plot of the percentage of iron versus the arsenic adsorption capacity of various adsorbents (soils or sediment). The HBHA pond (14.3 percent Fe) and wetland (6.6 percent Fe) data were plotted along with literature values obtained from Pierce and Moore (1982) for a pure  $\text{Fe}(\text{OH})_3$  (53 percent Fe), and Livesey and Huang (1981) for a black clay (1.5 percent Fe). The data fit the following power function with a squared correlation coefficient ( $r^2$ ) of 0.99:

$$A_M = 57(\text{Fe}\%)^{1.55}$$

Using the equation above, the adsorption capacity of a soil or sediment can be estimated given the percentage of iron in the material. However, the relationship is based on only four points, and is lacking data in the 20 to 50 percent iron range. Additional studies on post-batch adsorption sediment with the EM may provide adsorption capacities for

individual minerals such as biotite which can contain up to 33 percent iron, depending on the degree of magnesium substitution.

### Chromium

The results of the chromium adsorption study were as follows:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Initial Soil* Concentration (mg/kg)	Final Soil Concentration (mg/kg)
SED1-10	10	469	0.03	0.04	546	545.5
SED1-Cr	10	512	3.1	0.04	546	701

\* Measured by XRF by CDM

As shown in the table above, the final chromium concentration in both batches analyzed was 0.04 mg/L, despite the two-order-of-magnitude difference in initial solution concentrations. Unlike the arsenic isotherms, the equilibrium chromium concentration in solution does not increase with the soil concentration (see Figure 34). The isotherm instead forms a vertical line that is characteristic of a precipitation control on aqueous chromium concentrations. The final chromium concentrations in solution reflect the solubility of the chromium phase that is precipitating or dissolving. Therefore, the solubility of the chromium precipitate is 0.04 mg/L in the HBHA Pond sediment. Based on the work of numerous investigators published in the literature (Matzat and Shiraki 1978; Hem 1977, etc.) and on previous experience by CDM (CDM 1988; CDM 1995, etc.), trivalent chromium in nature is controlled by chromium oxyhydroxide precipitates, often in solid-solution with iron. However, the solubility of pure chromium hydroxide is only 0.002 mg/L at pH 7, and even lower for an iron-chromium hydroxide solid-solution phase. The higher than expected chromium concentrations suggest that chromium ions are being complexed, possibly by organic ligands. This organic complex may be responsible for the mobility of chromium at the Site.

Solubility control on chromium indicates infinite potential for the pond sediment to attenuate chromium down to the 0.04 mg/L level as long as the Eh and pH conditions are maintained.

### Benzene

The results of the benzene batch studies are provided in the following table:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Final Soil Concentration (mg/kg)
SED1-1	1	41.5	4.8	4.9	-4.0
SED1-2	2	40.7	4.8	4.2	11.9
SED1-4	4	38.6	4.8	4.0	7.6
SED1-7	7	34.2	4.8	3.0	8.8
SED1-10	10	31.7	4.8	2.6	6.9

Initial soil concentrations were assumed to be zero due to the drying and homogenization processes.

The resulting benzene isotherms for the HBHA pond sediment are presented in Figure 35. The best-fit Langmuir isotherm through the data result in an  $A_M$  of 19 mg/kg and a  $K_L$  of 0.5 mg/L. However, the curve does not go through the origin, but instead intercepts the Solution Concentration axis at about 0.7 mg/L. This implies that an addition of 0.7 mg/L of benzene to a clean (i.e., containing no benzene) pond sediment would result in no adsorption. Clearly, such a situation is not possible. One possible explanation is that benzene escaped from the VOA bottles via headspace loss. When the batches were prepared there was no headspace; however, following agitation air trapped within the pore spaces of the soils formed about a 5 mL headspace in the bottles. Another possible explanation is that the data should be fit to a linear isotherm rather than a Langmuir; however, such a fit results in a low correlation coefficient.

Assuming that volatilization losses are responsible for the non-zero intercept and that the volatilization losses were uniform among all 5 batches, the data can be corrected by moving the adsorption curve until it goes through the origin. When the curve is moved up 6 mg/kg, an  $A_M$  of 25 mg/kg is obtained (see the dashed curve in Figure 35). Note that  $K_L$  remains the same because the shape of the curve was not altered.

#### Toluene

The results of the toluene batch testing for the HBHA pond sediment are provided in the following table:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Final Soil Concentration- x/m (mg/kg)
SED1-1	1	41.5	0.19	0.16	1.2
SED1-2	2	40.7	0.19	0.15	0.8
SED1-4	4	38.6	0.19	0.11	0.7
SED1-7	7	34.2	0.19	0.09	0.5
SED1-10	10	31.7	0.19	0.04	0.4

The isotherm for the HBHA pond sediment is shown in Figure 36. The data appear to fit a linear isotherm, with a  $K_D$  of 7.7 L/kg. The correlation coefficient ( $r^2$ ) was 0.83.

A linear isotherm implies that the adsorption capacity is infinite. Obviously this is not the case. When a linear isotherm is fit to a set of data it represents only the best fit through that piece of the data. The straight line actually represents a small portion of a larger curve such as a Langmuir. The flat portion of the Langmuir curve is only revealed when a big enough spike is added to the solution to result in saturation of the soil. The batches in which linear isotherms resulted was for water in which no spike was added (i.e., toluene for the pond) or where the spike concentration was too low (i.e., benzene for the wetlands).

### 5.3 Biodegradation Capacity

As discussed in Section 2.3.3., ES&E performed biodegradation screening tests to evaluate the potential for microflora present in HBHA Pond sediment to biodegrade benzene and toluene in groundwater discharging to the HBHA Pond. Baseline characterization of the HBHA Pond sediment indicated that pH and moisture conditions in the pond sediment are within the optimal range for in-situ aerobic microbial degradation. A slight increase in pH (from 7.2 to 7.4) was also noted over the course of the 14-day biodegradation experiment, which is consistent with microbial activity.

Considerable losses of both benzene (approximately 77 percent) and toluene (approximately 82 percent) were measured in the HBHA Pond sediment (SED-1) over the 14-day experiment (Table 12, Figures 37 and 38). However, similar losses (i.e., 76 and 86 percent) were also noted in the sand control, which suggests that the reductions in benzene and toluene concentrations observed in the pond sediment sample may be attributable more to abiotic processes (e.g., volatilization, partitioning to sediment) than to microbial degradation. Since the experimental design did not include sampling of headspace and/or sediment benzene/toluene concentrations, the relative importance of the various removal mechanisms could not be evaluated.

It is also possible that biodegradation by microbial populations present in the groundwater from MC-1D may account for some of the benzene and toluene losses observed in the sand control. This hypothesis is supported by the observed loss of some benzene (8 percent) and toluene (16 percent) in the groundwater control sample (Table 12), which contained no sediment onto which benzene and/or toluene could adsorb, and no headspace into which benzene and/or toluene could volatilize. However, since no microbial plating or analyses for benzene or toluene metabolites (e.g., benzoic acid) was performed on the sand control, it is not possible to confirm this hypothesis.

#### 5.4 Projection of Long-Term Attenuation Capacity of HBHA Pond Sediments

Given the following input parameters, the effective adsorption "lifetime" remaining for the HBHA Pond sediment can be calculated:

Parameter	Value	Source
Groundwater inflow into HBHA Pond	0.48 cfs	Roux Associates, 1992
Average arsenic concentration	120 µg/L	MC-1 and MC-2
Remaining Sediment Adsorption Capacity	3,350-1,390 = 1,960 mg/kg*	SED1 0 - 1.5
Sediment Density	1.1 g/cm <sup>3</sup>	Roux Associates, 1992
Sediment Volume	7,400 m <sup>3</sup>	Roux Associates, 1992

\*The remaining sediment adsorption capacity is the difference between the total adsorption capacity ( $A_m$ ) and the concentration of arsenic that has already adsorbed onto the sediment.

The lifetime calculation follows:

##### Inflow Mass

$$(0.48 \text{ ft}^3/\text{sec}) (86,400 \text{ sec/day}) (7.48 \text{ gal./ft}^3) (3.79 \text{ L/gal.}) (120 \text{ µg/L})$$

$$= 1.4 \times 10^8 \text{ µg/day} = \mathbf{141,000 \text{ mg/day}}$$

##### Adsorption Capacity

$$(1,960 \text{ mg/kg}) (1 \text{ kg/1,000 g}) (1.1 \text{ g/cm}^3) (100 \text{ cm/m})^3 (7,400 \text{ m}^3)$$

$$= \mathbf{1.6 \times 10^{10} \text{ mg arsenic}}$$

##### Lifetime

$$(1.6 \times 10^{10} \text{ mg arsenic}) / (141,000 \text{ mg/day} * 365 \text{ days/yr}) = \mathbf{310 \text{ yr}}$$

A similar calculation performed for benzene resulted in a lifetime of 0.2 years.

The assumptions inherent in the above calculation follow:

- uniform distribution of contamination (water and sediment);
- representative samples of HBHA and Wetland sediment;
- uniform adsorption (no preferred paths);
- no new sediment is added;
- volume of sediment is accurate;
- groundwater inflow is accurate; and
- no other attenuation mechanisms (besides adsorption).

The above assumptions were made to simplify the calculations, and in most cases are conservative in nature. The validity and impact of each assumption are discussed in detail in the following paragraphs:

#### Uniform Distribution

Average values were used for the concentrations of arsenic and benzene in the groundwater, assuming these average concentrations were present within all inflowing groundwaters. However, in reality, some groundwaters are higher in arsenic and benzene, and some lower. Theoretically, pond sediment receiving higher-concentration groundwater could become saturated with arsenic or benzene sooner than predicted, while other areas would last longer.

The sediment was also assumed to have a uniform adsorption capacity, which implies that the soil is uniform in terms of the existing arsenic concentrations and the concentration of arsenic-adsorbing iron minerals.

#### Representative Sediment Samples were Collected

Only one sample was tested for adsorption capacity. The representative nature of the results should be determined by testing other samples to determine the variation in adsorption capacity.

#### Uniform Adsorption

The pond sediment can be described as a gelatinous ooze that is mostly water. The high water content and lack of compaction would suggest that adsorption would tend to be uniform (no channeling).

#### No New Sediment is Added

Three inlets (Hall's Brook, the Atlantic Avenue Drainway and an unnamed drainage near well MC-1) enter the HBHA Pond. All of the inlets have the potential for depositing new sediment into the pond, especially during storm events. Any new sediment would add more adsorption capacity and increase the adsorption lifetime. Therefore, this is a conservative assumption.

#### Volume of Sediment

The sediment volume was calculated from the sediment thickness and area data collected during the GSIP Phase 2 in RI 1991/1992. The volume of the pond sediment may have increased over the past 5 or 6 years due to sediment inflow from the inlets. A larger sediment volume would result in a longer lifetime than predicted above. Therefore, this is a conservative assumption.

#### Groundwater Flow

The groundwater flow was calculated based on a water balance calculation performed as part of the Oxygen Injection Demonstration Work Plan (Roux Associates, 1995). An overestimate of flow would result in an underestimate of the sediment lifetime and vice versa.

### Other Attenuation Mechanisms

The calculated "adsorption capacity" includes the removal mechanisms of adsorption, precipitation, and coprecipitation. This approach for arsenic is probably valid; however, benzene and toluene are subject to other attenuation mechanisms, such as volatilization and biodegradation. Therefore, the lifetime estimate for benzene is understated.

In addition to other mechanisms occurring, competition for adsorption sites should be evaluated. Because actual groundwater was used in the batch tests, competition between arsenic and other ions such as phosphate or selenate should already be accounted for. Should conditions change such that higher concentrations of phosphate or some other competing ion are introduced into the pond or groundwater in the future, the adsorption capacity of the sediment will be decreased. However, such an occurrence is not anticipated.

## **6.0 HBHA POND SURFACE WATER**

The results of the various components of the HBHA Pond surface-water investigation (i.e., surface-water geochemistry and residence time) are presented below.

### **6.1 Surface-Water Geochemistry**

As discussed in Section 2.4.1, multi-level surface-water samples (i.e., shallow, intermediate, and deep) were collected from the northern and southern ends of the HBHA Pond, and a single surface-water sample was collected from Hall's Brook immediately upstream of the pond (Figure 1). These data were collected to assess current geochemical conditions in pond surface water and to evaluate the efficiency with which pond sediment attenuate groundwater COCs as they discharge upward through the pond sediment. Surface-water geochemistry is discussed below, with the discussion being separated into two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Surface-water quality data are provided in Appendix E.

#### **6.1.1 COCs**

COC concentrations in HBHA Pond surface water are shown in Table 13 and in Figures 26 and 39 through 43. In general, the SSI surface-water data for the HBHA Pond are consistent with GSIP data, indicating that COC concentrations and distribution at the HBHA Pond have not changed significantly since the GSIP. The concentrations and distribution of each COC are discussed separately below.

##### **Benzene**

Benzene was detected only in the intermediate and deep surface-water samples (both filtered and unfiltered) collected from the southern end of the HBHA Pond (SW-2). No benzene was detected in the shallow sample collected at the southern end of the pond, nor in any of the samples collected at the northern end of the pond (SW-1) or in Hall's Brook immediately upstream of the pond (SW-6). The benzene concentration detected in the deep sample from the southern end of the pond (57 ug/L, filtered) was an order of

magnitude greater than the benzene concentration detected in the intermediate-depth sample (6 ug/L, filtered). However, as similar concentrations were detected in both the filtered and unfiltered samples at both horizons, the benzene is not thought to be associated with suspended sediment near the base of the pond.

The detection of benzene in surface water at depth in the southern end of the HBHA pond and the concentration at which benzene was detected are consistent with GSIP data (Figure 39). The absence of benzene in shallow surface water at both ends of the pond is also consistent with GSIP data (Figure 26). The absence of benzene at depth in the northern end of the pond, however, does not appear to be consistent with GSIP data, since benzene was detected at a concentration of approximately 1,300 ug/L in surface water immediately above the sediment-water interface during the GSIP Phase 2 RI (Figure 39) and because the benzene groundwater plume appears to be discharging to the northern end of the HBHA Pond.

#### Toluene

Toluene was detected at low concentrations (1 to 2 ug/L, estimated) in all of the surface-water samples (both filtered and unfiltered) collected from the HBHA Pond during the SSI. The data seem questionable at first review due to the consistency of the low concentrations detected, and may reflect laboratory contamination or instrumentation problems. However, no obvious data-quality deficiencies (e.g., contaminated lab or field blanks) were noted, and no toluene was detected in several other surface-water samples (e.g., SW-6, collected from Hall's Brook just upstream of the HBHA Pond) analyzed along with the HBHA Pond samples. Therefore, the data are considered valid.

The presence of toluene in HBHA Pond surface water is not consistent with GSIP data (Figure 26) as no toluene was detected in the pond during the GSIP.

### Arsenic

Arsenic was detected in all six of the unfiltered surface-water samples collected from the HBHA Pond. However, in the filtered samples, only the two deep (SW-IDF and SW-2DF) and one of the intermediate-depth samples (SW-1IF) contained detectable concentrations of arsenic. At both the northern and southern ends of the pond, the highest arsenic concentrations were detected in the deep samples, with the concentration in the southern end of the pond (34 ug/L, filtered) being somewhat higher than that in the northern end of the pond (18 ug/L, filtered). No arsenic was detected in Hall's Brook just upstream of the HBHA Pond.

The detection of arsenic in surface water in the HBHA Pond is consistent with GSIP data (Figure 40). Moreover, the concentrations detected in the deep samples are generally consistent with the concentrations detected immediately above the sediment-water interface during the GSIP Phase 2 RI (Figure 41), and confirm that the arsenic groundwater plume is discharging to surface water at the pond.

### Chromium

Chromium was detected in all six of the unfiltered surface-water samples collected from the HBHA Pond. However, in the filtered samples, only the two deep (SW-IDF and SW-2DF) and one of the intermediate-depth samples (SW-2IF) contained detectable concentrations of chromium, and all of these were below quantitation limits. Chromium was also detected in the unfiltered sample collected from Hall's Brook just upstream of the HBHA Pond, but was not detected in the filtered sample.

The detection of low concentrations of chromium in unfiltered samples of surface water from the HBHA Pond is consistent with GSIP data (Figure 42). The presence of low concentrations of chromium in filtered samples of deep surface water is also consistent with GSIP data (Figure 43).

### **6.1.2 Geochemical Indicator Parameters**

In general, the surface waters of the HBHA Pond have a higher Eh, and lower ferrous and total iron values than groundwater. The data are consistent, in that surface waters are in contact with atmospheric oxygen, which tends to raise the Eh, oxidize the ferrous iron to ferric, and precipitate  $\text{Fe}(\text{OH})_3$ . The HBHA Pond surface water collected near the bottom of the pond has more groundwater type characteristics, such as higher concentrations of ferrous iron (SW-1D and SW-2S) and Eh values as low as 132 (SW-1D) reflecting the findings of the modeling that Site groundwater is flowing into the pond.

### **6.2 Surface-Water Residence Time**

As discussed in Section 2.4.2, the residence time of surface water in the HBHA Pond was measured to evaluate how long COCs discharged from Site groundwater may potentially reside in the pond. Residence time was estimated by performing a dye study. A concentration-versus-time curve for the rhodamine dye injected into Hall's Brook just upstream of its mouth at the HBHA Pond is provided in Figure 44. As shown by the curve, rhodamine dye was detected by the portable rhodamine-dye detector placed at the outlet of the downstream wetlands within several hours of injection. (According to ES&E, some of the dye detected before 500 minutes is attributable to residual dye in the detector.) The maximum concentration was detected between approximately 900 and 1,000 minutes (15 to 16.5 hours) after injection. Assuming that the time at which the maximum concentration of dye passes the detector represents the average travel time of the dye (and associated surface water), the average residence time of surface water in the HBHA Pond and wetlands combined is approximately 15 to 16.5 hours.

The portion of the combined pond/wetland residence time that represents residence in the HBHA Pond was estimated by comparing theoretical travel times calculated for both the HBHA Pond and the downstream wetlands to the total theoretical travel time for the pond and wetlands combined. Theoretical travel times were calculated by dividing the total length of each surface-water segment (i.e., from the mouth of Hall's Brook to the pond

outlet [800 feet] for the pond segment, and from the pond outlet to the wetland outlet [3,000 feet] for the wetland segment) by the flow velocity measured along each segment during the GSIP. Flow measurements from GSIP surface-water gauging station SW-9 (0.02 feet per second) and SW-11 (0.01 feet per second) were averaged to obtain an average flow velocity for the HBHA Pond, while the flow measurement from SW-13 (0.26 feet per second) was used for the downstream wetlands. The resulting theoretical travel times, 14.8 hours and 3.2 hours (which together approximate quite closely the dye-estimated travel time of 15 to 16.5 hours), were compared to the total theoretical travel time for the pond and wetlands combined to calculate the percentage of the total travel time that represents residence in each segment. Based on the percentage of the total travel time that represents residence in the HBHA Pond (i.e., 82 percent), the average residence time of surface water in the HBHA Pond is estimated to be between 12.3 to 13.5 hours.

## **7.0 HBHA WETLAND**

The results of the various components of the HBHA wetland investigation (i.e., surface-water and sediment geochemistry, sediment adsorption and biodegradation capacity, and surface-water residence time) are presented below.

### **7.1 Surface-Water Geochemistry**

As discussed in Section 2.5.1, surface-water samples were collected from three locations downstream of the HBHA Pond (Figure 1) in order to assess current conditions in wetland surface water and to evaluate the efficiency with which the HBHA Pond and wetlands retain Site-related groundwater COCs once discharged into the pond. Surface-water geochemistry is discussed below in two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Surface-water quality data are provided in Appendix E.

#### **7.1.1 COCs**

COC concentrations in surface water in the HBHA wetlands are shown in Table 13, and in Figures 26, 40, and 42. In general, the SSI surface-water data for the wetland are consistent with GSIP data, indicating that COC concentrations and distribution in wetland surface water have not changed significantly since the GSIP. The concentrations and distribution of each COC are discussed separately below.

##### **Benzene**

Benzene was detected (4 ug/L, estimated) only in the filtered sample at SW-5, located downstream of the wetland outlet (i.e., downstream of the confluence with the Aberjona River). The absence of benzene in the wetland surface-water samples is consistent with GSIP data (Figure 26).

### Toluene

Toluene was detected at low concentrations (1 to 2 ug/L, estimated) in the filtered and unfiltered samples collected just downstream of the mouth of the HBHA Pond (i.e., at SW-3), but in none of the samples collected further downstream. The general absence of toluene in downstream wetland surface water is consistent with the GSIP data (Figure 26). The detection of toluene in surface water in the upstream reaches of the HBHA wetland, on the other hand, is not consistent with GSIP data. However, toluene has been detected at low concentrations (i.e., less than 10 µg/L) in surface water in the upstream reaches of the HBHA wetland during several post-GSIP surface-water monitoring events. A copy of the most recent HBHA surface-water monitoring report (July 1997) is provided in Appendix F.

### Arsenic

Arsenic was detected at low concentrations (approximately 10 to 15 µg/L) in all three of the unfiltered surface-water samples collected from the HBHA wetland, but in none of the filtered samples. Therefore, the arsenic detected in the unfiltered samples is likely associated with suspended sediment being transported to the wetland via surface water.

The detection of low concentrations of arsenic in unfiltered surface water in the HBHA wetland is consistent with GSIP data (Figure 40). The absence of arsenic in the filtered samples is not consistent with the GSIP data, as low levels (less than 10 ug/L) of arsenic were also detected in the filtered samples collected during the GSIP. This suggests that less dissolved arsenic was present in surface water during the SSI than during the GSIP.

### Chromium

Chromium was detected at low concentrations (less than 5 ug/L) in all three of the unfiltered surface-water samples collected from the HBHA wetland, but in none of the filtered samples. Therefore the chromium detected in the unfiltered samples is likely associated with suspended sediment being transported to the wetland via surface water.

The detection of low concentrations of chromium in unfiltered surface water in the HBHA wetland, but not in filtered samples, is consistent with GSIP data (Figure 42).

### **7.1.2 Geochemical Indicator Parameters**

The wetlands surface waters (SW-3, SW-4, and SW-5) have very similar characteristics to the shallow pond waters. The pH ranged from 6.24 to 7.56 for the wetland surface water compared to a range of 6.1 to 6.83 for the pond surface waters. The Eh values were also similar, with most waters having an Eh of about 300 mV. The total iron values were similar in both the pond (shallow) and the wetland surface waters. Apparently, the wetland surface water is derived from the shallow portion of the pond, and/or the shallow pond and wetlands have a similar source of water inflow (i.e., precipitation) or similar geochemical environments. The chemical data do not support a Site groundwater source to the wetlands, which is in agreement with the groundwater modeling results.

## **7.2 Sediment Geochemistry**

As discussed in Section 2.5.2, 2.5-foot long sediment cores were collected from three locations in the downstream wetlands (Figure 1) in order to assess current geochemical conditions in wetland sediment and to assess vertical gradations in sediment geochemistry. Wetland sediment geochemistry is discussed below in two parts: the first dealing with COCs, and the second dealing with geochemical indicator parameters. Sediment-quality data are provided in Appendix B.

### **7.2.1 COCs**

COC concentrations in HBHA wetland sediment are shown in Table 11. In general, the SSI sediment data for the wetland are consistent with GSIP data, indicating that COC concentrations and distribution in the wetland sediment have not changed significantly since the GSIP. The concentrations and distribution of each COC are discussed separately below.

### Benzene

Benzene was not detected in any of the sediment samples collected in the HBHA wetland. This is consistent with GSIP data (Figure 26).

### Toluene

Toluene was detected at very low concentrations (2 ug/kg) in three of the ten wetland sediment samples. In the upstream location (SED-3), toluene was detected in the uppermost two horizons (0 to 0.5 foot and 0.5 to 1 foot), while toluene was detected in the deepest horizon (2.0 to 2.5 feet) in the downstream sample. As discussed in Section 6.1.1, it is possible that the toluene detections represent a laboratory artifact, as the low concentrations are consistent with the level of contamination reported for many of the surface-water samples. However, these toluene detections currently appear valid.

The detection of toluene in wetland sediment is not consistent with GSIP data, as toluene had never been detected in wetland sediment previously (Figure 26).

### Arsenic

Arsenic was detected in all ten sediment samples collected in the HBHA wetland. Arsenic concentrations detected in the downstream samples (SED-4) are over an order of magnitude higher than those detected in the upstream samples (SED-3). This disparity is attributed to the different characteristics of the samples, which in turn is a reflection of the differences in sampling locations: SED-4 was a generally silty sample collected in a quiescent ponded area, while SED-3 was a sandier sample collected adjacent to a fast-moving channel. Since metals such as arsenic adsorb readily to fine-grained sediment, which are more abundant in the SED-4 core, such a trend is expected. Similarly, at both sampling locations, the arsenic concentrations detected in the upper, silty part of the cores are also much higher than those detected in the lower, sandy part. However, within a given sediment type (i.e., silt or sand), no trend was observed with depth in the cores. In fact, at SED-4, which contained between 1.5 and 2 feet of fine-grained sediment, the maximum arsenic concentration was detected in the 1- to 1.5- foot interval.

The detection of arsenic in HBHA wetland sediment and the concentrations at which arsenic was detected are both consistent with GSIP data (Figure 28). No data were developed for deeper horizons in the wetland during the GSIP, however, so no direct comparison to GSIP data can be made.

### Chromium

Chromium was also detected in all ten sediment samples collected in the HBHA wetland. As was the case with arsenic, chromium concentrations detected in the downstream samples (SED-4) are over an order of magnitude higher than those detected in the upstream samples (SED-3), and chromium concentrations detected in the upper, silty part of the cores are also much higher than those detected in the lower, sandy part. This disparity is again attributed to the affinity of metals for fine-grained sediment, which are more abundant at SED-4 than at SED-3, and in the upper part of both cores. In addition, the maximum chromium concentration was also detected in the 1- to 1.5- foot interval at SED-4, just as it was with arsenic.

The detection of chromium in HBHA wetland sediment and the concentrations at which chromium was detected are both consistent with GSIP data (Figure 30). As was the case with arsenic, no data were developed for deeper horizons in the wetland during the GSIP, however, so no direct comparison to GSIP data can be made.

### **7.2.2 Geochemical Indicator Parameters**

The forms of sulfur in the wetlands sediment samples were as follows:

Sample ID	Pyritic (mg/kg)	Organic (mg/kg)	Sulfate (mg/kg)	Total (mg/kg)
SED3 0-0.5	0.04	0.16	0.01	0.2
SED3 0.5-1.0	0.01	0.01	0.01	0.01
SED3 1-1.5	0.01	0.01	0.01	0.01
SED3 1.5-2	0.01	0.01	0.01	0.01

Sample ID	Pyritic (mg/kg)	Organic (mg/kg)	Sulfate (mg/kg)	Total (mg/kg)
SED3 2-2.5	0.01	0.02	0.01	0.02
SED4 0-0.5	0.03	0.08	0.01	0.11
SED4 0.5-1.0	0.01	0.01	0.01	0.01
SED4 1.0-1.5	0.01	0.01	0.01	0.01
SED4 1.5-2.0	0.01	0.02	0.01	0.03
SED4 2.0-2.5	0.03	0.01	0.01	0.01

Like the HBHA Pond sediment, the most abundant form of sulfur is organically bound, followed by pyritic. However, the concentrations are very low, except the surface samples (0-0.5 feet) which may represent a more organic-rich material. The surface samples, however, have much lower concentrations than those from the HBHA Pond.

### 7.2.3 Electron Microscopy

#### SED4 - 1-1.5 and SED4 - 1.5-2

The wetlands samples were characterized by arsenic adsorbed onto iron minerals. Unlike the HBHA pond sediment, iron sulfates were not identified. Arsenic adsorption occurred exclusively onto iron minerals such as biotite, amphiboles or pyroxenes. In some cases, arsenic-bearing biotites (iron-bearing mica) were identified next to muscovite (non iron-bearing mica), with no detectable arsenic. Photomicrographs 5, 6, and 7 Appendix D are examples of biotite grains with adsorbed arsenic, while photomicrographs 8 and 9 Appendix D show iron-bearing silicate minerals such as pyroxene or amphiboles containing about 0.15 percent arsenic.

### 7.3 Adsorption Capacity

#### Arsenic

The results of the batch adsorption study for arsenic were as follows:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Initial Soil* Concentration (mg/kg)	Final Soil Concentration (mg/kg)
SED3-10	10	469	10	0.3	113	567
SED3-15	10	465	15	0.24	113	782
SED3-20	10	475	20	0.38	113	1,060
SED3-25	11	448	25	0.65	113	1,149
SED3-30	10	453	30	5.3	113	1,223

\* Measured by XRF 4/27/97 in CDM's Denver Laboratory

Like the HBHA Pond sediment, the data conform to the Langmuir Adsorption Model (see Figure 45). When the HBHA wetland sediment data are fitted to the Langmuir model as shown in Figure 45, an  $A_M$  of 1,500 mg/kg and a  $K_L$  of 5 mg/L was obtained.

#### Chromium

The results of the chromium adsorption study were as follows:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Initial Soil* Concentration (mg/kg)	Final Soil Concentration (mg/kg)
SED3-10	10	469	0.012	0.018	107	106.7
SED3-Cr	10	515	3.4	0.018	107	278

\* Measured by XRF 4/27/97 in CDM's Denver Laboratory

In the wetlands batch in which the initial chromium concentration was 0.012 mg/L, chromium increased to produce a final solution concentration of 0.018 mg/L (see Figure 46). In the batch containing an initial chromium spike of 3.4 mg/L, chromium decreased

to a final concentration of 0.018. Chromium appears to be controlled by a precipitate with a solubility of 0.018 mg/L.

Solubility control on chromium indicates infinite potential for the wetlands sediment to attenuate chromium down to about 0.02 mg/L as long as the Eh and pH conditions are maintained.

#### Benzene

The results of the benzene batch studies were as follows:

Sample ID	Soil Mass (grams)	Solution Volume (mL)	Initial Solution Concentration (mg/L)	Final Solution Concentration (mg/L)	Final Soil Concentration (mg/kg)
SED3-1	1	42	2.6	2.3	13.2
SED3-2	2	42	2.6	2.0	12.8
SED3-4	4	42	2.6	2.0	6.5
SED3-7	7	40	2.6	1.5	6.4
SED3-10	10	39	2.6	1.5	4.4

The resulting benzene isotherm for the wetland sediment is presented in Figure 47. The isotherm appears to be linear, but as for the HBHA Pond sediment, the x intercept is not zero. Moving the curve up 8.9 mg/kg results in a linear isotherm with a  $K_D$  (slope) of 9.5 L/kg. The correlation coefficient ( $r^2$ ) was 0.65.

#### Toluene

Note that toluene was not present in the MC-3S groundwater and was not spiked; therefore, no isotherm was calculated for toluene in the wetland sediment.

#### **7.4 Biodegradation Capacity**

Baseline characterization of the wetland sediment indicated that pH and moisture conditions in the wetland sediment are within the optimal range for *in situ* aerobic microbial degradation. A moderate increase in pH (6.6 to 7.4) was also noted over the course of the 14-day biodegradation experiment, which is consistent with microbial activity.

Considerable losses of both benzene (approximately 83 percent) and toluene (approximately 92 percent) were measured in the wetland sediment (SED-4) over the 14-day experiment (Table 12, Figures 37 and 38). Slightly lower, but still notably high, losses (approximately 75 and 76 percent, respectively) were also noted for the abiotic control, suggesting that the reductions in benzene and toluene concentrations observed in the wetland sediment sample may be attributable in part to abiotic processes (e.g., volatilization, partitioning to sediment) as well as to microbial degradation. As was the case with the pond sediment (SED-1), the experimental design did not include sampling of headspace and/or sediment benzene/toluene concentrations, and the relative importance of the various removal mechanisms could not be ascertained. In addition, since no microbial plating or analyses for benzene or toluene metabolites (e.g., benzoic acid) was performed on the abiotic control sample, it is not possible to evaluate whether biodegradation by microbial populations present in the groundwater from MC-1D may account for some of the benzene and toluene losses observed in the abiotic control sample.

#### **7.5 Surface-Water Residence Time**

As discussed earlier in Section 3.4.2, based on the concentration-versus-time curve for the rhodamine dye injected into Hall's Brook just upstream of its mouth at the HBHA Pond (Figure 44), the average residence time of surface water in the HBHA Pond and wetlands combined is approximately 15 to 16.5 hours. As was done for the HBHA Pond (Section 3.4.2), the portion of the combined pond/wetland residence time that represents residence in the downstream wetland was estimated by comparing theoretical travel times calculated

for both the HBHA Pond and the downstream wetlands to the total theoretical travel time for the pond and wetlands combined. Based on the percentage of the total travel time that represents residence in the downstream wetland (i.e., 18 percent), the average residence time of surface water in the downstream wetland is estimated to be between 2.7 to 3.0 hours.

## **8.0 SIGNIFICANT CONCLUSIONS OF THE SUPPLEMENTAL SITE INVESTIGATION**

Based on the findings of the various work elements conducted during the SSI, the environmental fate and transport conclusions set forth in the GSIP have been updated and expanded. Those expanded conclusions are presented below in a “source-to-sink” fashion, beginning with the mobilization of COCs at the source areas, then describing the current and long-term fate and transport of the COCs as they migrate in groundwater away from potential source areas and to the HBHA Pond, where they are attenuated by HBHA Pond sediment as groundwater discharges into the HBHA Pond.

### COC Release Mechanisms in Source Areas

Based on the data developed during the GSIP and the SSI, it appears that the stockpiling of anaerobically-decaying hide residues atop arsenic- and chromium-containing soils during development of the Site in the late 1970s resulted in the creation of environmental conditions facilitating the mobilization of arsenic and chromium from the Site soils. Specifically, groundwater and precipitation percolating through the anaerobically-decaying hide residues is reduced through contact with the decaying hide residues. The reduced groundwater then infiltrates the arsenic- and chromium-containing soils underlying the hide piles, leaching arsenic and chromium from the soils, largely in the more mobile, reduced forms of these metals (e.g., arsenic III and organically-complexed arsenic and chromium compounds). The extent to which arsenic and chromium are leached from the metals-containing soils, and the forms of arsenic and chromium present in the leachate, are controlled by the oxidation-reduction potential of the infiltrating water, as demonstrated by Envirogen’s column study. Specifically, more arsenic and chromium are leached, and more mobile forms are produced, by water with lower oxidation-reduction potentials.

Presently, the source-area groundwater appears to be less strongly-reducing than it was during the GSIP, which was conducted between 1990 and 1992. Specifically, Eh conditions measured at source areas during the SSI increased compared to Eh’s measured in source-area groundwater during the GSIP. This increase in oxidation of the source-

area groundwater appears to be the result of one of two factors, or perhaps a combination of the two:

- site remedial measures (e.g., capping of the Site) implemented since completion of the GSIP in 1992 have reduced the amount of precipitation that infiltrates through the hide residues; and/or
- the amount of organic material available for leaching has decreased (via consumption) since the GSIP, which was conducted between 1990 and 1992.

As would be expected based on the results of Envirogen's column study, the less reducing conditions present at the hide piles today appear to have resulted in less leaching of arsenic and chromium, and the production of generally less mobile forms of these metals. Specifically, arsenic and chromium concentrations detected during the SSI are generally less than those detected during the GSIP (c. 1990 - 1992), particularly at the West and East-Central Hide Piles, and at the Arsenic Pit. In addition, the majority of the source-area arsenic is now present in the oxidized, less mobile arsenic V form.

In addition to the arsenic and chromium sources, potential benzene and toluene source areas were also identified during previous investigations. These source areas include the following:

- a potential benzene source area located northeast of the South Hide Pile and directly south of Atlantic Avenue; and
- a potential toluene source area located near the southeast corner of the East-Central Hide Pile.

Despite extensive investigation during the 1980s and early 1990s using geophysical methods, soil borings, and temporary monitoring wells, no significant area of benzene soil contamination was ever found. Moreover, GSIP data, along with other data developed during the early 1990s, indicated that a benzene "hot spot" had migrated away from the potential benzene source area northeast of the South Hide Pile to an area adjacent to the northern end of the HBHA Pond. Benzene concentrations at the South Hide Pile and near the HBHA Pond appear to be generally the same today as they were during the GSIP.

Toluene concentrations at the East-Central Hide Pile, on the other hand, appear to have decreased significantly since the GSIP (c. 1990 - 1992), suggesting a reduction in the strength of the toluene source in that area, or a reduction in leaching of the source area due to Site remedial measures completed since the GSIP.

#### Fate and Transport of COCs Downgradient of Source Areas

Once COCs have entered into the groundwater, their migration is governed by the groundwater flow regime at and downgradient of the Site. This groundwater flow regime is, in turn, controlled by surface-water features and the geometry of the underlying buried-valley aquifer. The buried-valley aquifer is characterized by a series of upgradient branch valleys underlying the Site which merge together into a main trunk valley in the vicinity of the HBHA Pond. Groundwater containing COCs moves downgradient down each of the branch valleys, and flows upward and discharges to surface water in the HBHA Pond. Apparently, but to a lesser degree (i.e., only for some of the groundwater migrating from the area of the West Hide Pile), some groundwater discharges to the New Boston Street Drainway, a tributary of Hall's Brook and the HBHA Pond. Consequently, the HBHA Pond acts as the "endpoint" for the groundwater COC plumes migrating away from source areas at the Site. This conclusion, that the HBHA Pond acts as the "endpoint" for the groundwater COC plumes at the Site, was first set forth in the GSIP and is supported by the water-level data developed for the area near the HBHA during the SSI. This conclusion is further supported by CDM's initial groundwater modeling efforts, which indicate that, even with sensitivity-analysis changes in key variables, such as hydraulic conductivity of the aquifer and bedrock topography, modeled groundwater discharge from identified potential source areas is still to the HBHA Pond, or to the New Boston Street Drainway (a tributary of the pond), in the case of groundwater moving downgradient from the West Hide Pile.

As Site-related COCs migrate downgradient toward the HBHA Pond, they enter an area of the aquifer characterized by conditions more oxidizing than those present in the source areas. Here, arsenic and chromium concentrations in groundwater are attenuated (via

adsorption and/or precipitation within the aquifer matrix) due to the change to more oxidizing conditions. More reducing conditions may exist, however, in limited areas of the aquifer, particularly at depth, where more of the organic matter from the source areas is present in groundwater. In these organic-material-rich areas of the aquifer, arsenic and chromium attenuation appears to be limited, as the arsenic and chromium remain in reduced forms instead of being oxidized and adsorbing/precipitating out with iron hydroxides.

Little attenuation of benzene and toluene appears to take place in the aquifer downgradient of their source areas.

#### Environmental Fate of COCs in Groundwater Discharging to the HBHA Pond

As groundwater discharges to the HBHA Pond, bio- and geochemical processes taking place in the pond sediment filter out or metabolize the COCs from the discharging groundwater, such that only low concentrations of dissolved COCs are present in pond surface water, and generally only at the base of the pond. A major conclusion of the SSI is that these processes continue today to effectively remove COCs from discharging groundwater.

The particular mechanisms responsible for the removal of COCs prior to groundwater discharge vary. Adsorption to iron-bearing pond sediment and co-precipitation with iron sulfates and iron hydroxides appear to be the mechanisms by which arsenic and chromium are attenuated. The role of organic carbon in sequestering arsenic and chromium appears to be minimal. This represents a slight modification of the GSIP conclusions that chromium, in particular, complexed with sedimentary organic carbon in the pond sediment and was thus filtered out of the discharging groundwater.

Biodegradation appears to be the mechanism most responsible for attenuation of benzene and toluene. Biodegradation of benzene and toluene is believed to be occurring in the HBHA Pond sediment for the following reasons:

- a previous comparison of the benzene concentrations in groundwater beneath the HBHA Pond and the benzene concentrations in surface water at the base of the pond (Roux Associates, 1995) indicated that greater than 90 percent of the mass of benzene discharging to the HBHA Pond is removed as groundwater moves upward through the pond sediment.
- benzene is known to be readily biodegradable; and
- GSIP studies showed that microbes in HBHA Pond sediment thrive on a benzene food source.

COCs adsorbed onto HBHA Pond sediment are generally retained in the pond, due to the relative quiescence of the pond bottom, which is, in turn, a function of the pond's morphology (i.e., the pond was designed as a storm-water retention basin). The pond's sediment-retention efficiency is demonstrated by the presence of over 1 foot of extremely fluid fine-grained sediment at the base of the pond, all of which has accumulated since the 1970s. However, based on the detection of COCs (i.e., arsenic and chromium) on suspended solids at the outlet from the HBHA Pond, some limited downstream transport of sediment-adsorbed metallic COCs to the HBHA wetland appears to occur.

Residence times for surface water in the HBHA Pond and particularly in the HBHA wetlands appear to be too short to provide significant attenuation of any COCs that may potentially break through to surface water. However, no significant concentrations of COCs (i.e., greater than approximately 10 to 15 ug/L) appear to migrate beyond the HBHA Pond and wetlands via the surface-water pathway.

#### Long-Term Environmental Fate Issues

Based on adsorption-capacity "lifetime" calculations performed during the SSI, the HBHA Pond sediment appears to have an unlimited capacity (based on current trends in Eh/pH conditions) to attenuate chromium in discharging groundwater, since potential chromium concentrations in pore water are limited by the relatively low solubility of the chromium precipitate present in the sediment. The sediment's capacity to attenuate arsenic discharging to the pond is estimated to be at least several hundred years. However,

additional arsenic adsorption will likely be accompanied by increased pore-water concentrations of arsenic. The sediment's capacity to adsorb benzene was calculated to be less than 1 year, assuming no biodegradation were occurring. However, although not quantified during the SSI, biodegradation appears to be the dominant mechanism for benzene and toluene removal from discharging groundwater.

#### Data Gaps

The SSI conclusions reflect the most current and comprehensive understanding of the environmental fate of COCs at the Site. Nonetheless, the SSI, together with the GSIP, suggest that some additional investigation is appropriate. The items warranting additional investigation include the following:

- the trend toward less-reducing conditions at the suspected source areas;
- toluene reductions in the suspected toluene source areas;
- mechanisms for biodegradation of benzene in HBHA Pond sediment;
- potential remobilization of COCs in HBHA Pond sediments, particularly during storm events; and
- the source and extent of arsenic detected in the MC-3 MicroWell™ cluster.

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## TABLES

Table 1. Supplemental Site Investigation MicroWell™ Construction Details,  
Industri-Plex Site, Woburn, Massachusetts

Monitoring Location Designation	Total Depth of Well (feet below land surface)	Screened Internal (feet below land surface)			Screened Interval (feet above mean sea level)		
MC-1S	18.0	7.0	-	17.0	50.3	-	40.3
MC-1I	31.0	20.0	-	30.0	37.4	-	27.4
MC-1D	44.0	33.0	-	43.0	24.4	-	14.4
MC-2S	15.0	4.0	-	14.0	50.0	-	40.0
MC-2I	28.0	17.0	-	27.0	37.1	-	27.1
MC-2D	41.0	30.0	-	40.0	24.2	-	14.2
MC-3S	17.0	6.0	-	16.0	47.9	-	37.9
MC-3I	47.0	36.0	-	46.0	17.4	-	7.4
MC-3D	83.0	72.0	-	82.0	-18.5	-	-28.5

Table 2. Supplemental Site Investigation Ground-Water Analytical Data,  
Industri-Plex Site, Woburn, Massachusetts

Source Area Ground Water

Sample Location Designation	Parameter: Concentration:	Benzene (µg/L)	Toluene (µg/L)	Arsenic (µg/L)	Chromium (µg/L)
GW-1		10 U	10 U	5 U	1 U
GW-2		10 U	10 U	31.8	16.8
GW-3		10 U	4 J	451	35.9
GW-4		1,000	150	718	132
GW-5		10 U	10 U	51.4	48.9

Downgradient Ground Water

Sample Location Designation	Parameter: Concentration:	Benzene (µg/L)	Toluene (µg/L)	Arsenic (µg/L)	Chromium (µg/L)
MC-1S		160	10 U	45.5	18.1
MC-1I		160	10 U	547	25.6
MC-1D		14,000	420 J	60 U	80.2 B
MC-2S		10 U	10 U	12.6	1 U
MC-2I		10 U	10 U	8.8 B	1 U
MC-2D		10 U	10 U	6 U	1 U
MC-3S		10 U	10 U	164	1.6 B
MC-3I		10 U	10 U	6 U	1 U
MC-3D		10 U	10 U	6 U	1 U

Notes:

µg/L - micrograms per liter

U - indicates that the compound was analyzed for but not detected (value shown is contract-required detection limit)

J - indicates that the compound was analyzed for and determined to be present at an estimated concentration greater than zero and less than the contract-required detection limit

B - indicates that the metal was analyzed for and determined to be present at an estimated concentration greater than zero and less than the contract-required detection limit

**Table 3. Comparison of SSI and GSIP Data for  
Source-Area Groundwater**

Parameter	Units	West Hidepile			Arsenic Pit		East Central Hidepile		South Hidepile		
		GW-1	WP-5	OW-36	GW-2	OW-43	GW-3	OW-16	GW-4	OW-54C	OW-12
pH	s.u.	6.7	6.7	8.4	4.1	6.2	7.3	7.4	7.7	7.8	7.6
				6.9				6.9			8.2
Eh	mV	109	-68	370	269	390	86	310	-47	136	-72
								-59.2			-91.7
											-54.9
											-56.1
TOC	mg/L	7.4		9	8.58	17	7.3/47.1	230	<1		160
								2730			29
								2770			
S <sup>2-</sup>	mg/L	<1		<1	<1	<1	<1	2	<1		23
								0.2			0.084
								0.11			
Fe (Total)	mg/L	4.21	60	0.67	24.7	37.1	1.14	0.87	1.8	0.8	5.13
								1.29			<0.12
Fe <sup>2+</sup>	mg/L	2.11		0.02	4.96	7.5	3.71	5.3	1.34		18
HCO <sub>3</sub> <sup>-</sup>	mg/L	237		800	3.8	320	2030	11100	6400		5000
											935
SO <sub>4</sub> <sup>2-</sup>	mg/L	527		118	573	799	19.3	<5	<10		1780
Cr (Total)	mg/L	<0.001	<0.004	0.008	0.017	0.008	0.036	0.138	0.132	0.1	0.0355
				0.121		0.003		0.252			0.0498
Cr (III)	mg/L	1.07			0.53		1.17	0.16	0.64		
Cr (VI)	mg/L	<0.05		<0.01	<0.05	<0.01	<0.05	<0.01	<0.05		<0.01
As (Total)	µg/L	<5.0	869	440	41.1	2800	417	2300	579	949	900
								2860			280
								2400			422
								1700			36
As (III)	µg/L	0.26			0.15		136	530	57.4		<5
As (V)	µg/L	0.13			30.3		279	620	421		450
As (Organic)	µg/L	0.18		<2	10.6	<2	2	600	101		21
NH <sub>3</sub> -N	mg/L	1.61		<0.1	2.11	3	422	2300	1270		7960

SSI Data = GW-1, GW-2, GW-3, and GW-4  
GSIP Data= OW-36, WP-5, OW-43, OW-16, OW-54C and OW-12

Table 4. Concentration and Speciation of Arsenic in Background Waters and in Column Eluates Before and After Attaining Reduced Conditions

Water Source <sup>a</sup>	Concentration of Arsenic Species (µg/L)						Total Reduced Arsenic <sup>d</sup>
	Total Arsenic	Inorganic Arsenic	Arsenic (III)	Arsenic (V) <sup>b</sup>	MMA <sup>c</sup>	DMA <sup>c</sup>	
Background Water	4.2	2.35	0.02	2.33	0.01	<0.01	1.87
Initial Effluent	473	383	390	0	<1.6	<1.6	473
Final Effluent	2,165	805	540	265	<1.6	<1.6	1,900

<sup>a</sup> Background water was collected before passing through the test column. Initial effluent water was collected from the column before anaerobic conditions had been established (ORP=+83.5 mV). The final effluent was collected after anaerobic conditions had been established (ORP=-86 mV). The condition of this final effluent water is considered to be most representative of conditions expected below the hide piles when sufficient DOC is available to create highly reducing conditions.

<sup>b</sup> Arsenic (V) is calculated by [inorganic arsenic - arsenic (III)].

<sup>c</sup> MMA = monomethyl arsenate; DMA = dimethyl arsenate

<sup>d</sup> Total reduced arsenic is calculated by [(total arsenic - inorganic arsenic) + arsenic (III)].

Source: Envirogen

Table 5. Supplemental Site Investigation Water-Level Elevation Data, Industri-Plex Site, Woburn, Massachusetts

Monitoring Location Designation	MP Elevation (feet above mean sea level)	Depth to Water (feet below measuring point)	Water Level Elevation (feet above mean sea level)
<b>MicroWells™</b>			
MC-1S	59.31	7.15	52.16
MC-1I	59.43	6.99	52.44
MC-1D	59.42	7.04	52.38
MC-2S	56.12	4.05	52.07
MC-2I	56.17	3.94	52.23
MC-2D	56.27	3.74	52.53
MC-3S	56.00	3.92	52.08
MC-3I	55.45	3.33	52.12
MC-3D	55.54	3.25	52.29
<b>Stream Gauges</b>			
SG-1	54.37	2.44	51.93
SG-2	54.89	2.96	51.93
SG-3	54.19	2.38	51.81

MP - measuring point

**Table 6:**  
***Variation of Simulated Water Levels Relative to Average Observed Values 1991 - 1992***  
**"OW" Well Series**

Run Description	Mean Difference	Standard Deviation
Base case: Kxy = 75 ft/day, Kz = 3.75 ft/day	-0.36	1.24
Base case with sediment layer around pond	0.327	1.75
Kz reduced to 0.75 ft/day	-0.317	1.32
Kz increased to 7.5 ft/day	-0.554	1.26
Kxy reduced to 50 ft/day	-0.332	1.29
Kxy increased to 150 ft/day	-0.678	1.30
Kxy reduced to 50 ft/day and Kz reduced to 0.75 ft/day	-0.121	1.34
Kxy increased to 150 ft/day and Kz increased to 7.5 ft/day	-0.724	1.28
Recharge Increased by 25%	-0.253	1.25
Recharge Decreased by 25%	-0.469	1.24
Ecology and Environment Bedrock Interpretation	-0.194	1.42

**Table 7:**  
***Variation of Simulated Water Levels Relative to Average Observed Values 1997***  
***MicroWell Clusters***

Run Description	Mean Difference	Standard Deviation
Base case: Kxy = 75 ft/day, Kz = 3.75 ft/day	-0.046	0.561
Base case with sediment layer around pond	1.301	1.631
Kz reduced to 0.75 ft/day	0.213	0.614
Kz increased to 7.5 ft/day	-0.157	0.526
Kxy reduced to 50 ft/day	-0.044	0.524
Kxy increased to 150 ft/day	-0.086	0.582
Kxy reduced to 50 ft/day and Kz reduced to 0.75 ft/day	0.269	0.57
Kxy increased to 150 ft/day and Kz increased to 7.5 ft/day	-0.171	0.553

<b>Table 8:</b> <b>Measured and Simulated Heads at MicroWell Clusters and Hall's Brook Holding Area</b> <b>(heads reported in ft. MSL)</b>				
ID	Measured Value	Base Case	Kz reduced to 0.75 ft/day	Kz Increased to 7.5 ft/day
Pond	51.93	52	52	52
MC-1S	52.16	52.85	52.93	52.71
MC-1I	52.44	52.93	53.18	52.75
MC-1D	52.38	53.13	53.72	52.85
MC-2S	52.07	52.12	52.24	52.08
MC-2I	52.23	52.14	52.33	52.09
MC-2D	52.53	52.17	52.45	52.1
MC-3S	52.08	51.49	51.7	51.42
MC-3I	52.12	51.52	51.82	51.43
MC-3D	52.29	51.54	51.84	51.45

<b>Table 8 (continued):</b> <b>Measured and Simulated Heads at MicroWell Clusters and Hall's Brook Holding Area</b> <b>(heads reported in ft. MSL)</b>			
ID	Measured Value	Base Case	Base Case with pond Sediment
Pond	51.93	52	52
MC-1S	52.16	52.85	55.23
MC-1I	52.44	52.93	55.72
MC-1D	52.38	53.13	55.79
MC-2S	52.07	52.12	53.27
MC-2I	52.23	52.14	53.47
MC-2D	52.53	52.17	53.51
MC-3S	52.08	51.49	51.63
MC-3I	52.12	51.52	51.68
MC-3D	52.29	51.54	51.71

<b>Table 9:</b> <b>Simulated Local Groundwater Discharge</b> <b>(ft<sup>3</sup>/day)</b>			
Run Description	Model Locations		
	Groundwater Inflow to HBHA Pond	Flow Out of Southern Boundary	Total Flow Out of Model
Base case: Kxy = 75 ft/day, Kz = 3.75 ft/day	27,300	17,077	208,915
Base case with sediment layer around pond	9,401	17,097	208,923
Recharge Increased by 25%	29,561	20,423	261,003
Recharge Decreased by 25%	25,516	13,717	156,626
Ecology and Environment Bedrock Interpretation	35,743	17,416	209,380

<b>Table 10:</b> <b>Simulated Local Groundwater Discharge and Measured Total Flows</b> <b>at Surface Water Measuring Points (ft<sup>3</sup>/day)</b>					
Run Description	Station Name				
	SW-5	SW-10	SW-12	SW-13	SW-14
October 4, 1991 Measured Flow:	97,632	241,056	167,616	282,528	527,904
Base case: K <sub>xy</sub> = 75 ft/day, K <sub>z</sub> = 3.75 ft/day	41,142	59,250	57,745	86,549	193,207
Base case with sediment layer around pond	44,831	74,477	61,989	83,878	193,195
Recharge increased by 25%	57,738	73,225	79,187	102,787	241,978
Recharge decreased by 25%	22,850	45,518	33,459	71,034	144,249
Ecology and Environment bedrock interpretation	22,983	63,554	33,810	99,296	193,326

Table 11. Supplemental Site Investigation Sediment Analytical Data, Industri-Plex Site, Woburn, Massachusetts.

Sample Location Designation	Lithology	Parameter: Concentration:	Benzene (µg/kg)	Toluene (µg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)
SED-1 0-1.5'	Organic Silt		4,100	10 U	1,390	1,060
SED-1 1.5-2.5'	Sand		34	2 J	18.3	15.0
SED-2 0-0.5'	Organic Silt		400	14 J	1,270	711
SED-3 0-0.5'	Organic Silt		10 U	2 J	35.2	26.3
SED-3 0.5-1.0'	Sand		10 U	2 J	13.3	6.4
SED-3 1-1.5'	Sand		10 U	10 U	11.7	6.0
SED-3 1.5-2'	Sand		10 U	10 U	7.7	3.8
SED-3 2-2.5'	Sand		10 U	10 U	12.5	6.1
SED-4 0-0.5'	Organic Silt		10 U	10 U	419	664
SED-4 0.5-1'	Organic Silt		10 U	10 U	397	517
SED-4 1-1.5'	Organic Silt		10 U	10 U	603	983
SED-4 1.5-2'	Organic Silt/Sand		10 U	10 U	503	910
SED-4 2-2.5'	Sand		10 U	2 J	56.6	56.7

Notes:

µg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

U - indicates that the compound was analyzed for but not detected (value shown is contract-required detection limit)

J - indicates that the compound was analyzed for and determined to be present at an estimated concentration greater than zero and less than the contract-required detection limit

Table 12. Average Percent Benzene and Toluene Remaining in Overlying Water After 14 Days of Exposure to Sediments<sup>a</sup>

Sample ID	PERCENT BENZENE REMAINING			
	DAY 2	DAY 4	DAY 7	DAY 14
Water	NA	NA	NA	92*
Sediment 1	56.8	40.9	37.0	22.9
Sediment 4	56.6	29.1	21.2	17.2
Abiotic Control	63.7	36.3	30.2	24.7
Sand Control	63.4	53.3	44.7	23.6

Sample ID	PERCENT TOLUENE REMAINING			
	DAY 2	DAY 4	DAY 7	DAY 14
Water	NA	NA	NA	84*
Sediment 1	56.9	41.4	18.4	18.1
Sediment 4	55.8	29.3	19.0	7.7
Abiotic Control	60.0	35.9	26.3	23.7
Sand Control	55.6	49.1	38.4	13.8

\*This water sample was taken on day 0 without headspace and kept for the duration of the study.

<sup>a</sup>All the results are averages of duplicate measurements

Source: ES&E

Table 13. Supplemental Site Investigation Surface-Water Analytical Data,  
Industri-Plex Site, Woburn, Massachusetts

Sample Location Designation	Parameter: Concentration:	Benzene (µg/L)	Toluene (µg/L)	Arsenic (µg/L)	Chromium (µg/L)
SW-1S		10 U	1 J	7.1 B	2 B
SW-1S F		10 U	1 J	6 U	1 U
SW-1I		10 U	2 J	13.9	1.9 B
SW-1I F		10 U	1 J	8.2 B	1 U
SW-1D		10 U	1 J	51.8	14.6
SW-1D F		10 U	1 J	18.1	1.3 B
SW-2S		10 U	1 J	6.9 B	1.1 B
SW-2S F		10 U	1 J	6 U	1 U
SW-2I		2 J	1 J	11.7	1.4 B
SW-2I F		6 J	1 J	6 U	1 U
SW-2D		80	2 J	617	225
SW-2D F		57	2 J	33.9	5 B
SW-3		10 U	2 J	14.2	4.8 B
SW-3 F		10 U	1 J	6 U	1 U
SW-4		10 U	10 U	7.8 B	3.7 B
SW-4 F		10 U	10 U	6 U	1 U
SW-5		10 U	10 U	8.2 B	1.4 B
SW-5 F		4 J	10 U	6 U	1 U
SW-6		10 U	10 U	6 U	3.1 B
SW-6 F		10 U	10 U	6 U	1 U

Notes:

µg/L - micrograms per liter

F - indicates filtered sample

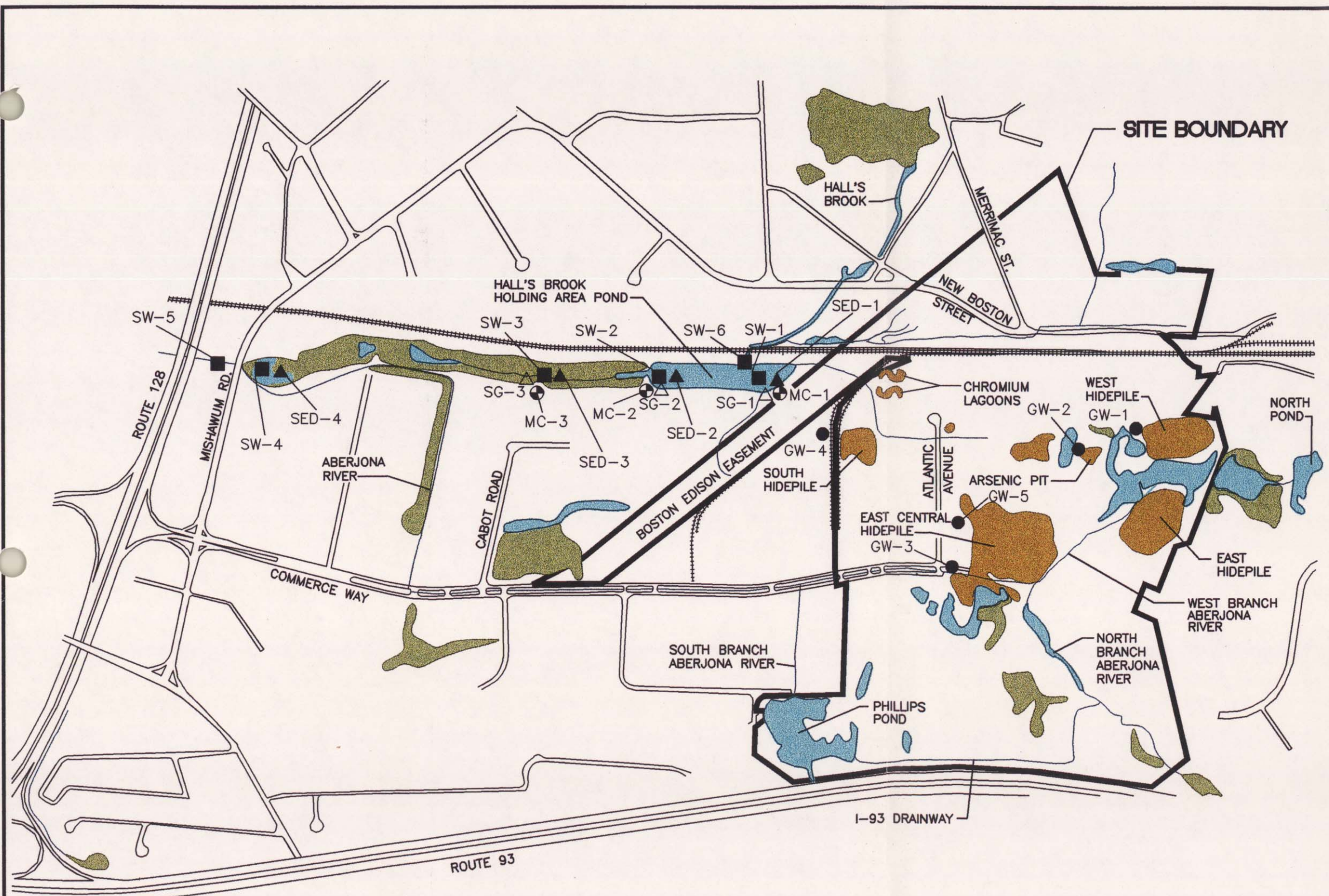
U - indicates that the compound was analyzed for but not detected (value shown is contract-required detection limit)

J - indicates that the compound was analyzed for and determined to be present at an estimated concentration greater than zero and less than the contract-required detection limit

B - indicates that the metal was analyzed for and determined to be present at an estimated concentration greater than zero and less than the contract-required detection limit

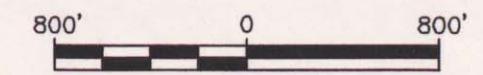
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## FIGURES



**EXPLANATION**

- POTENTIAL SOURCE AREAS
- WETLANDS
- SURFACE WATER BODIES
- GW-1 ● LOCATION AND DESIGNATION OF GEOPROBE GROUND-WATER SAMPLING POINT
- MC-1 ⊙ LOCATION AND DESIGNATION OF MICROWELL CLUSTER
- SW-1 ■ LOCATION AND DESIGNATION OF SURFACE-WATER SAMPLING POINT
- SED-3 ▲ LOCATION AND DESIGNATION OF SEDIMENT SAMPLING POINT
- SG-1 △ LOCATION AND DESIGNATION OF STREAM GAUGE



Title:

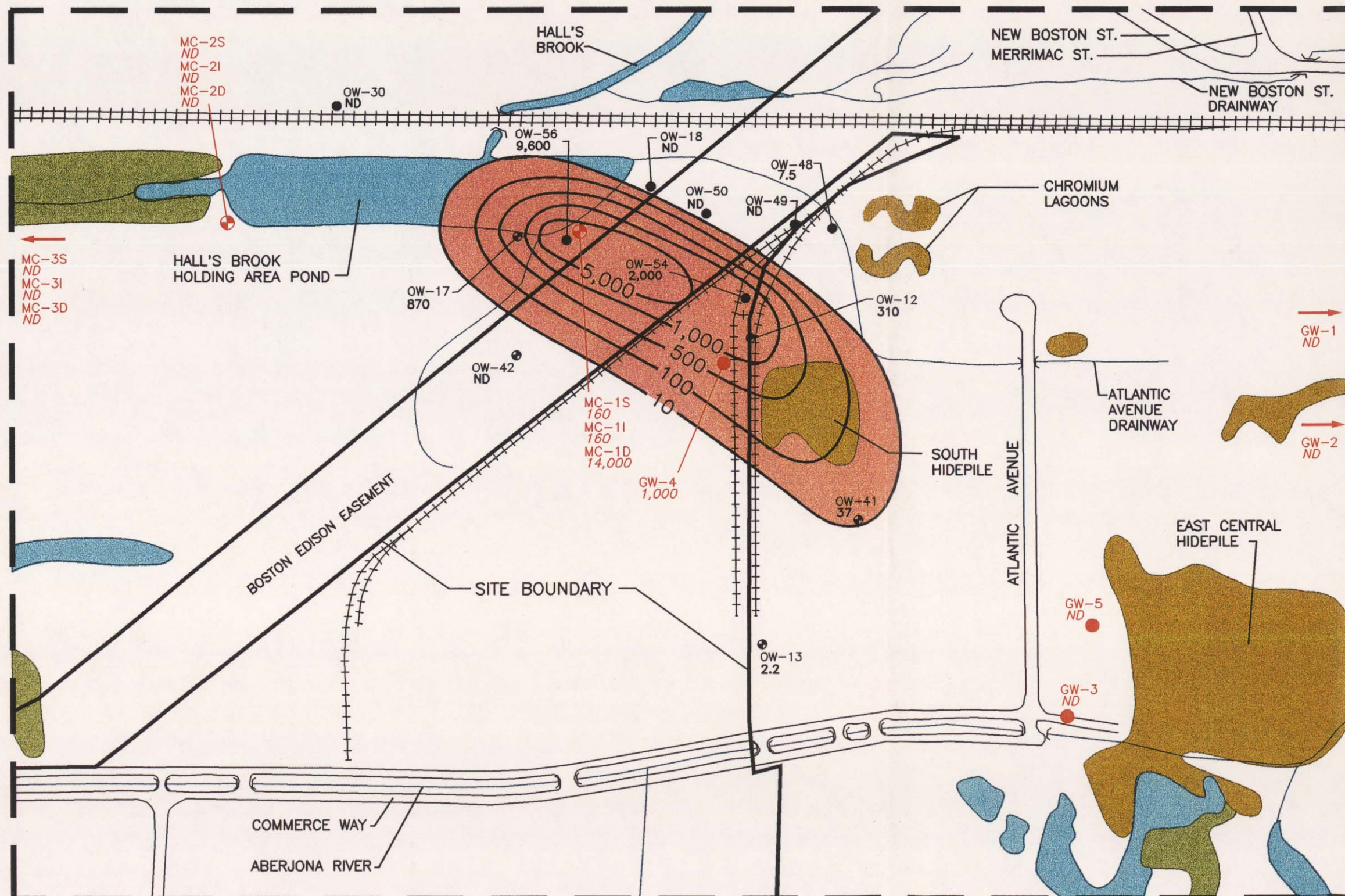
## SUPPLEMENTAL SITE INVESTIGATION SAMPLING LOCATIONS

SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

INDUSTRI-PLEX SITE REMEDIAL TRUST

 <b>ROUX ASSOCIATES INC</b> <small>Environmental Consulting &amp; Management</small>	Compiled by: S.W.	Date: 9/97	FIGURE  <b>1</b>
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610607	Project: 06626M10	



# EXPLANATION

- MC-3S ND LOCATION AND DESIGNATION OF SSI MICRO WELL CLUSTER
- CONCENTRATION OF BENZENE IN GROUND WATER, MEASURED IN MICROGRAMS PER LITER (ug/L)
- GW-4 LOCATION AND DESIGNATION OF SSI GEOPROBE SAMPLING POINT
- OW-12 310 LOCATION AND DESIGNATION OF FORMER SINGLE MONITORING WELL
- CONCENTRATION OF BENZENE IN GROUND WATER IN 1992, MEASURED IN ug/L
- OW-18 LOCATION AND DESIGNATION OF FORMER TWO- OR THREE-WELL CLUSTER
- ND - NOT DETECTED
- 10 LINE OF EQUAL BENZENE CONCENTRATION, IN ug/L
- INDICATES DIRECTION OF GROUND-WATER SAMPLING POINT LOCATED OFF OF MAP
- POTENTIAL SOURCE AREAS
- WETLANDS
- SURFACE WATER BODIES
- EXTENT OF GROUND WATER CONTAINING BENZENE AT CONCENTRATIONS EXCEEDING 10 ug/L, BASED UPON 1992 DATA

NOTES: 1. EXTENT OF BENZENE PLUME ADAPTED FROM FIGURE 3.5 OF PRELIMINARY DESIGN REPORT FOR INTERIM GROUNDWATER REMEDY.

2. FOR WELL CLUSTERS, THE MAXIMUM BENZENE CONCENTRATION DETECTED IS SHOWN.

300' 0 300'

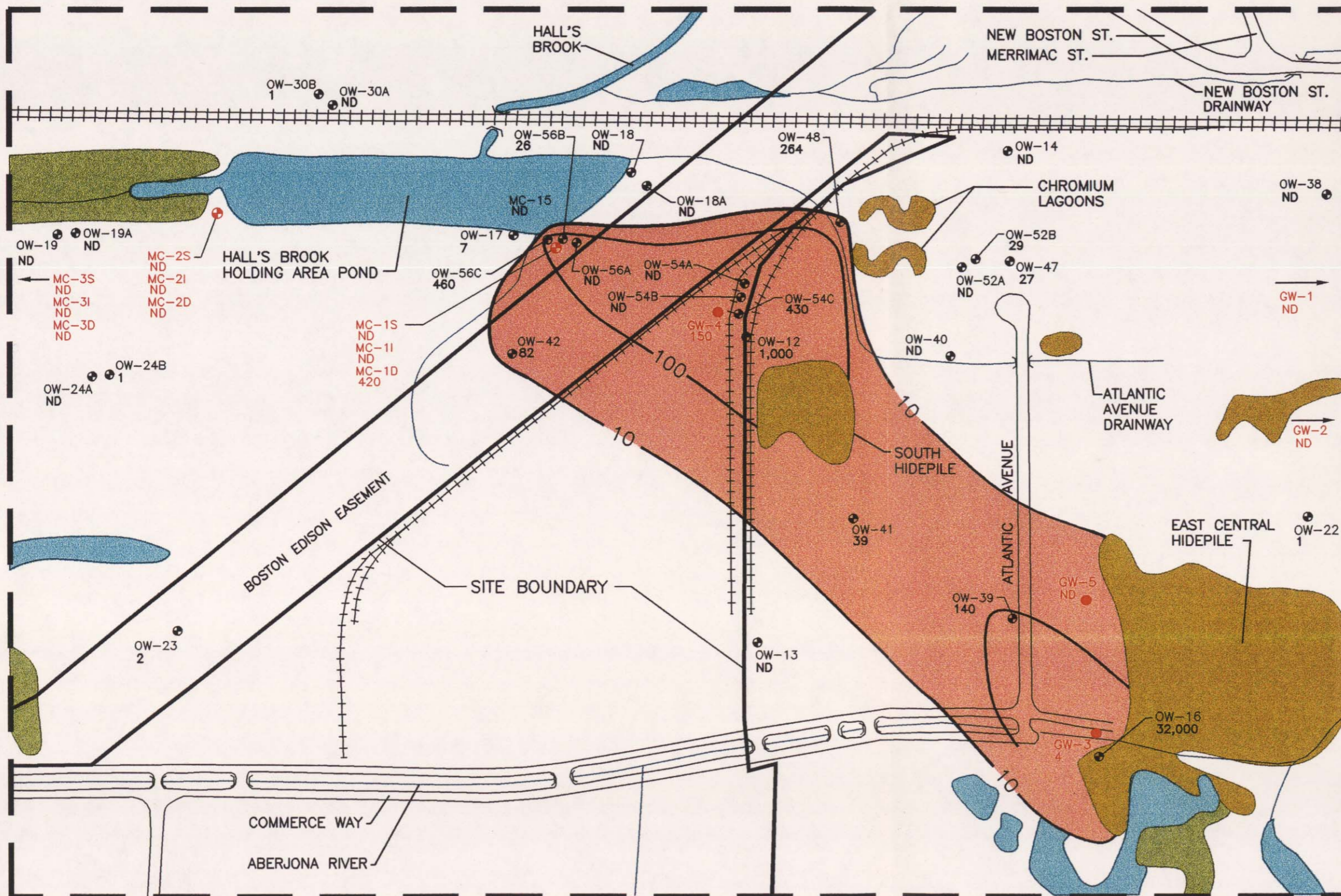
Title:

EXTENT OF BENZENE IN GROUND WATER

SUPPLEMENTAL SITE INVESTIGATION

Prepared For: INDUSTRI-PLEX SITE REMEDIAL TRUST

<b>ROUX</b> ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: S.W.	Date: 9/97	FIGURE 2
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610608	Project: 06626M10	



**LEGEND**

- MC-3S ND LOCATION AND DESIGNATION OF SSI MICRO WELL CLUSTER
- CONCENTRATION OF TOLUENE IN GROUND WATER, MEASURED IN MICROGRAMS PER LITER (ug/L)
- GW-4 LOCATION AND DESIGNATION OF SSI GEOPROBE SAMPLING POINT
- OW-12 1,000 LOCATION AND DESIGNATION OF FORMER MONITORING WELL
- MAXIMUM CONCENTRATION OF TOLUENE DETECTED IN GROUND WATER IN 1990 AND 1991, MEASURED IN ug/L
- ND - NOT DETECTED
- 10 LINE OF EQUAL TOLUENE CONCENTRATION, IN ug/L
- POTENTIAL SOURCE AREAS
- WETLANDS
- SURFACE WATER BODIES
- EXTENT OF GROUND WATER CONTAINING TOLUENE AT CONCENTRATIONS EXCEEDING 10 ug/L IN 1991-92

NOTES: 1. DATA SHOWN ARE MAXIMUM TOLUENE CONCENTRATIONS DETECTED DURING SAMPLING EVENTS CONDUCTED DURING THE PDI AND GSIP RI, BETWEEN MARCH 1990 AND DECEMBER 1991.

2. EXTENT OF TOLUENE PLUME ADAPTED FROM PLATE 6 OF GSIP PHASE 2 RI REPORT (ROUX ASSOCIATES, INC. 1992)

300' 0 300'

Title:

# EXTENT OF TOLUENE IN GROUND WATER

SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

INDUSTRI-PLEX SITE REMEDIAL TRUST

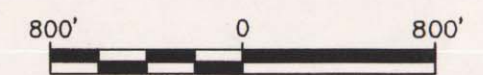
<b>ROUX</b> ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: L.M.	Date: 9/97	FIGURE
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610609	Project: 06626M10	

3



EXPLANATION

- AREAS OF BURIED-VALLEY AQUIFER WITH ARSENIC CONCENTRATIONS EXCEEDING FEDERAL MAXIMUM CONCENTRATION LEVEL OF 50 MICROGRAMS PER LITER, AS MEASURED DURING THE GSIP
- AREAS BEYOND LIMITS OF BURIED-VALLEY AQUIFER
- POTENTIAL SOURCE AREA
- WETLANDS
- SURFACE WATER BODIES
- GW-2 32 LOCATION AND DESIGNATION OF SSI GEOPROBE SAMPLING POINT  
CONCENTRATION OF ARSENIC MEASURED IN MICROGRAMS PER LITER
- MC-3S 4 LOCATION AND DESIGNATION OF SSI MICRO WELL CLUSTER  
CONCENTRATION OF ARSENIC MEASURED IN MICROGRAMS PER LITER
- ND NOT DETECTED



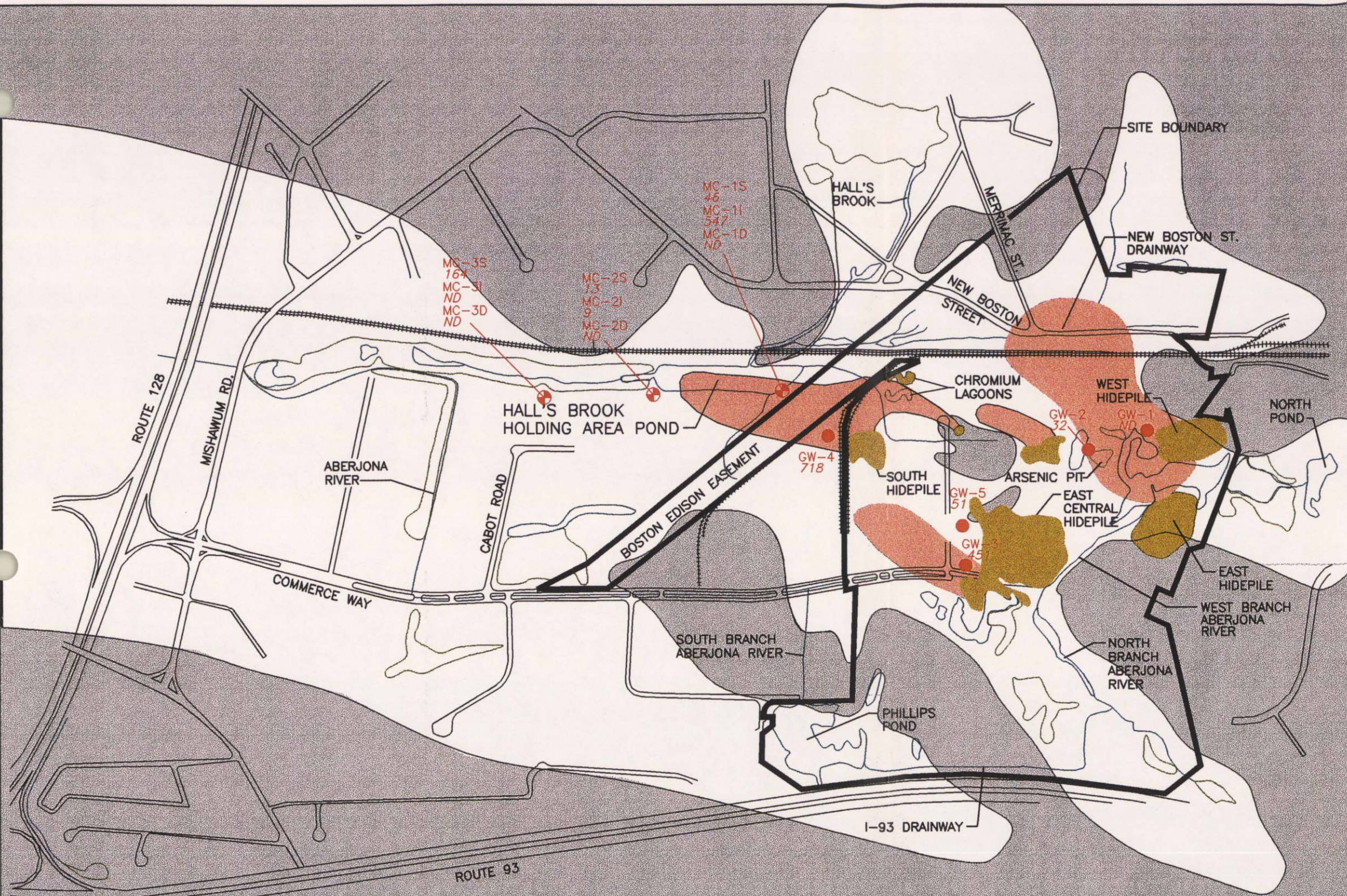
Title:

EXTENT OF ARSENIC  
IN GROUND WATER

SUPPLEMENTAL SITE INVESTIGATION

Prepared For:  
INDUSTRI-PLEX SITE REMEDIAL TRUST

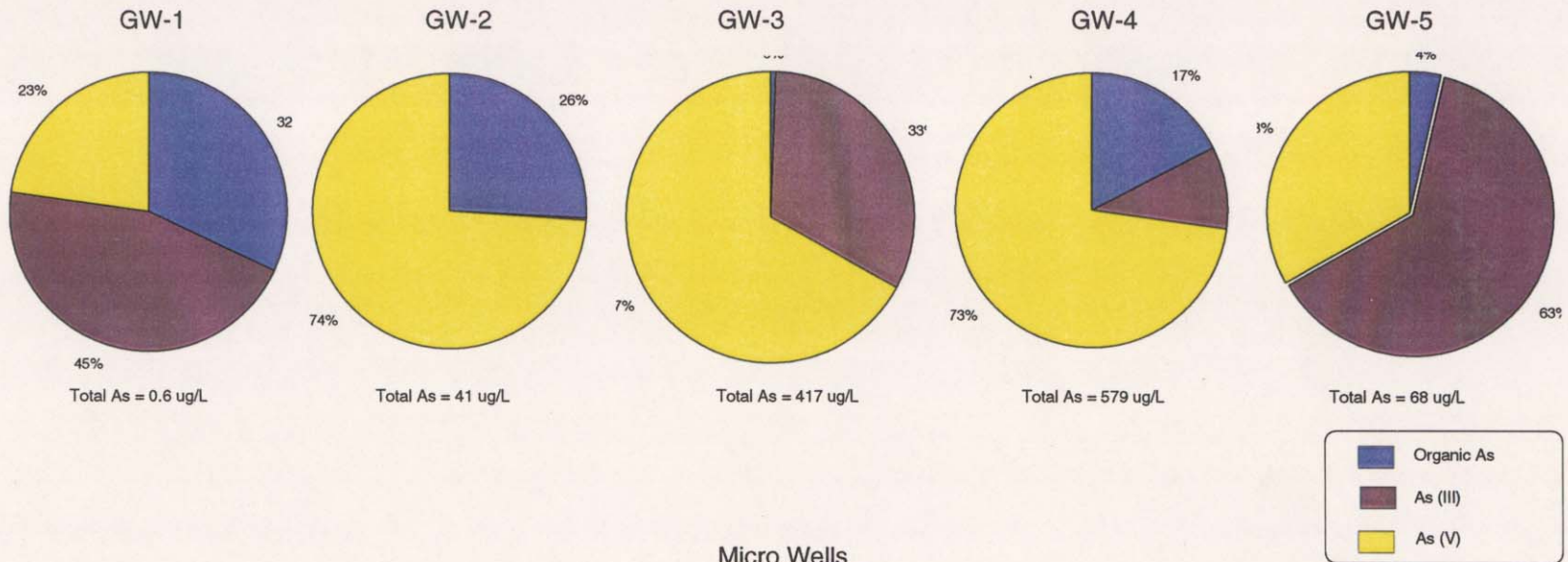
<b>ROUX</b> ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: S.W.	Date: 9/97	FIGURE 4
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610610	Project: 06626M10	





## As Speciation

### Source Groundwaters



### Micro Wells

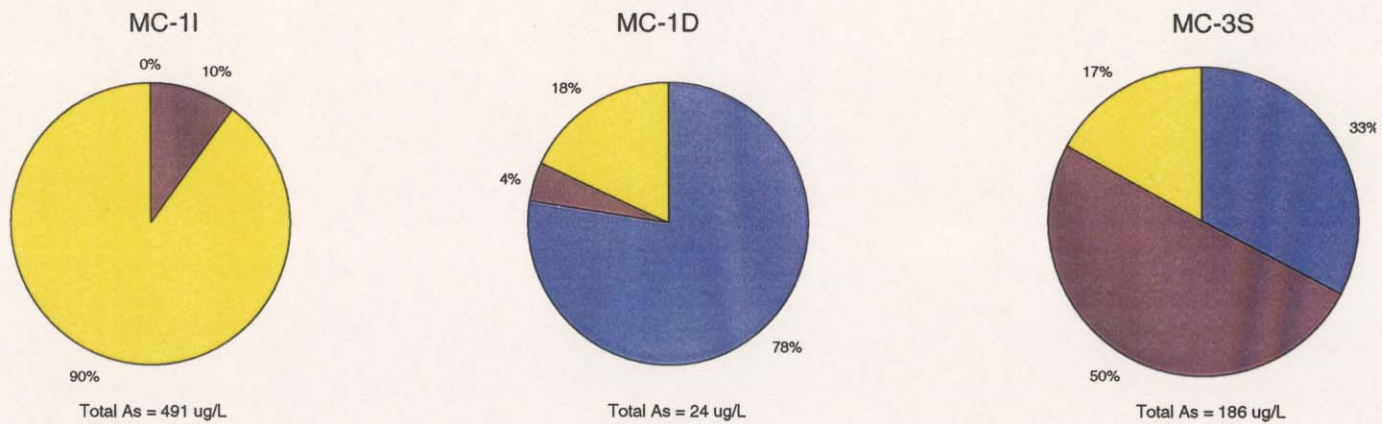


Figure 6 Arsenic speciation pie diagrams

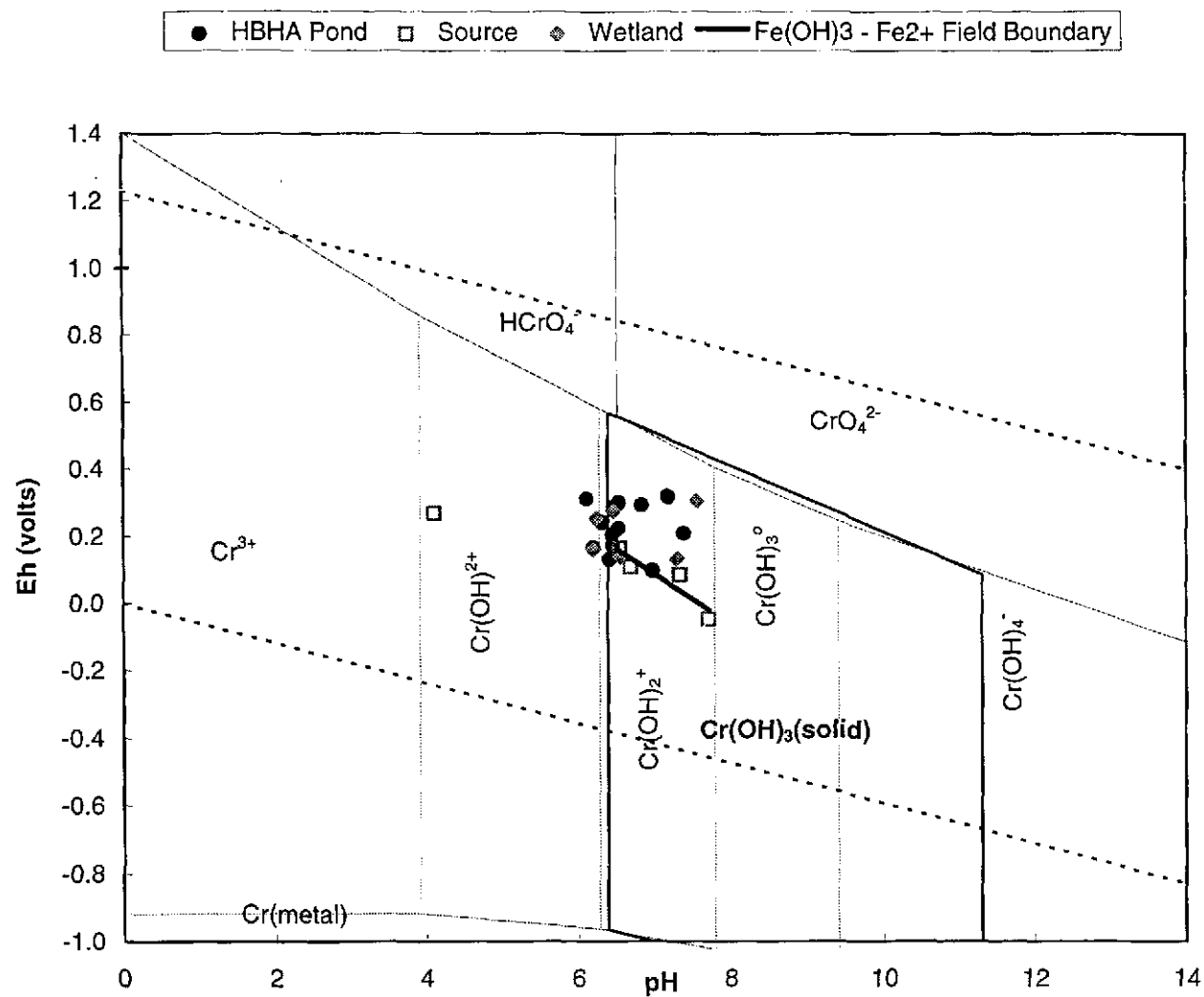


Figure 7 Eh-pH diagram for system Cr-O-H at 25°C and 1 atm. Aqueous Cr  $1 \times 10^{-7}$  for equilibrium with Cr(metal) and Cr(OH)<sub>3</sub>(solid). Thermodynamic data from Richard and Bourg (1991). Circles represent field measurements.

=

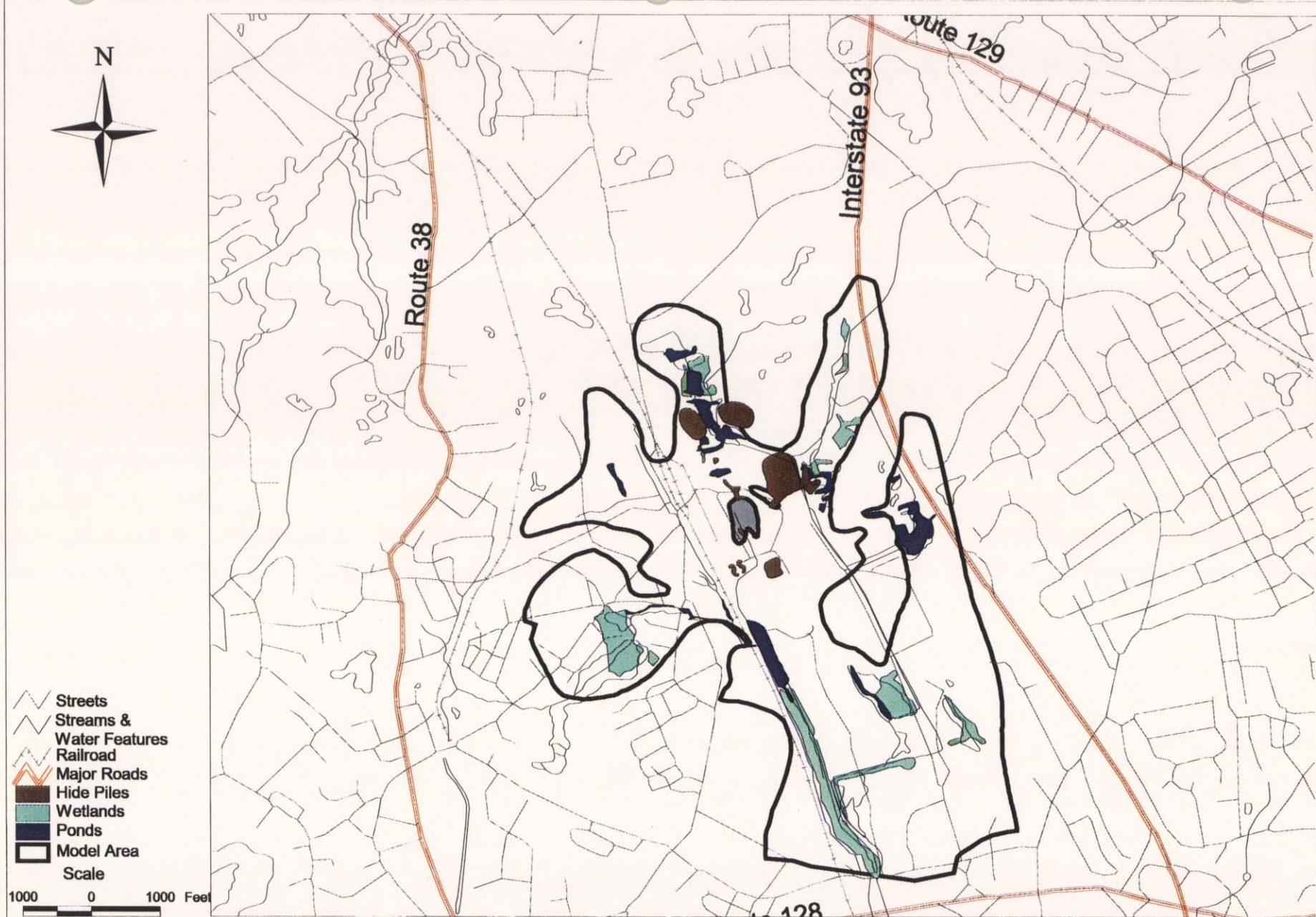


Figure 8: Map of Site Features and Model Outline

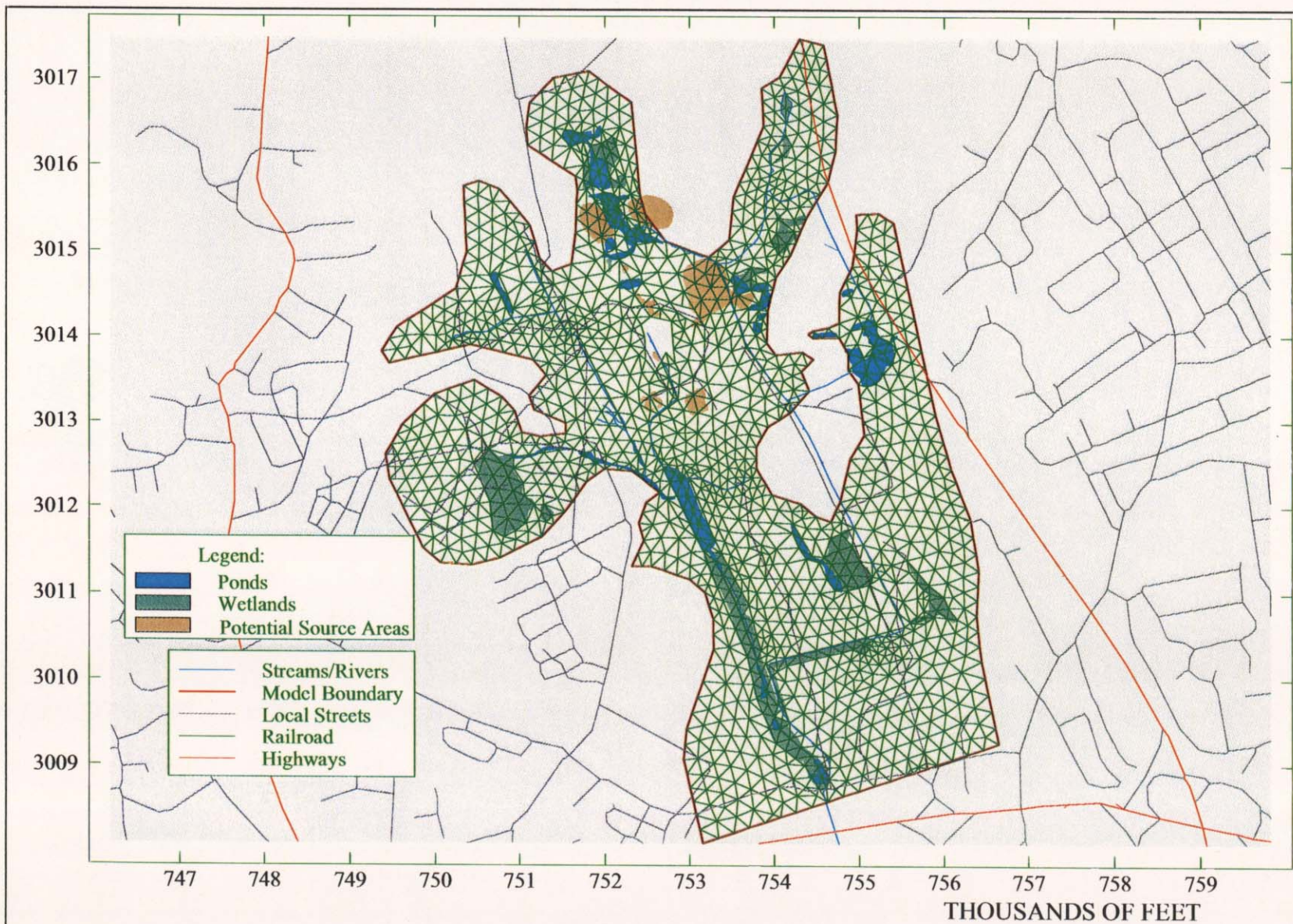


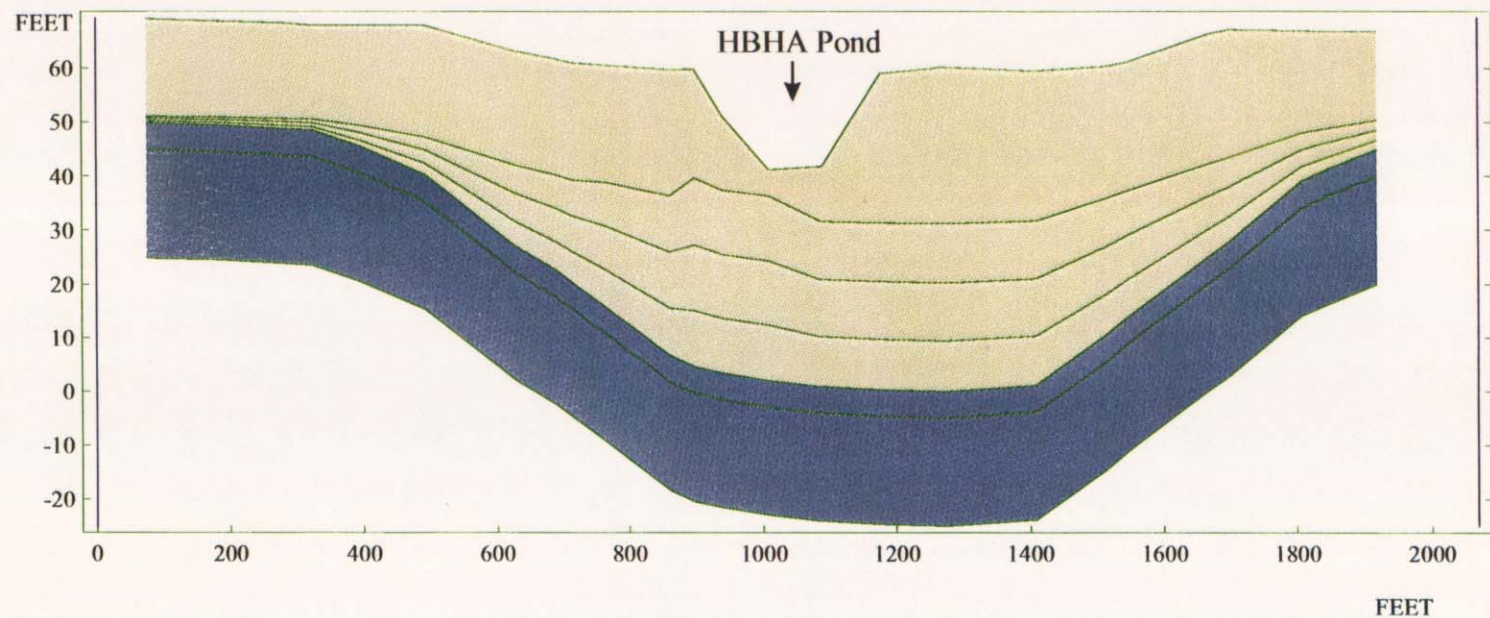
FIGURE  
9

Model Finite Element Grid

Industri-Plex Groundwater Model, Woburn, MA

**CDM**

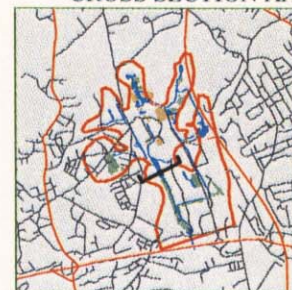
environmental engineers, scientists,  
planners, & management consultants



**MATERIALS CROSS-SECTION AA**

- Outwash  $K_h = 75 \text{ f/d}$
- Bedrock  $K_h = 0.5 \text{ f/d}$

**CROSS SECTION AA**

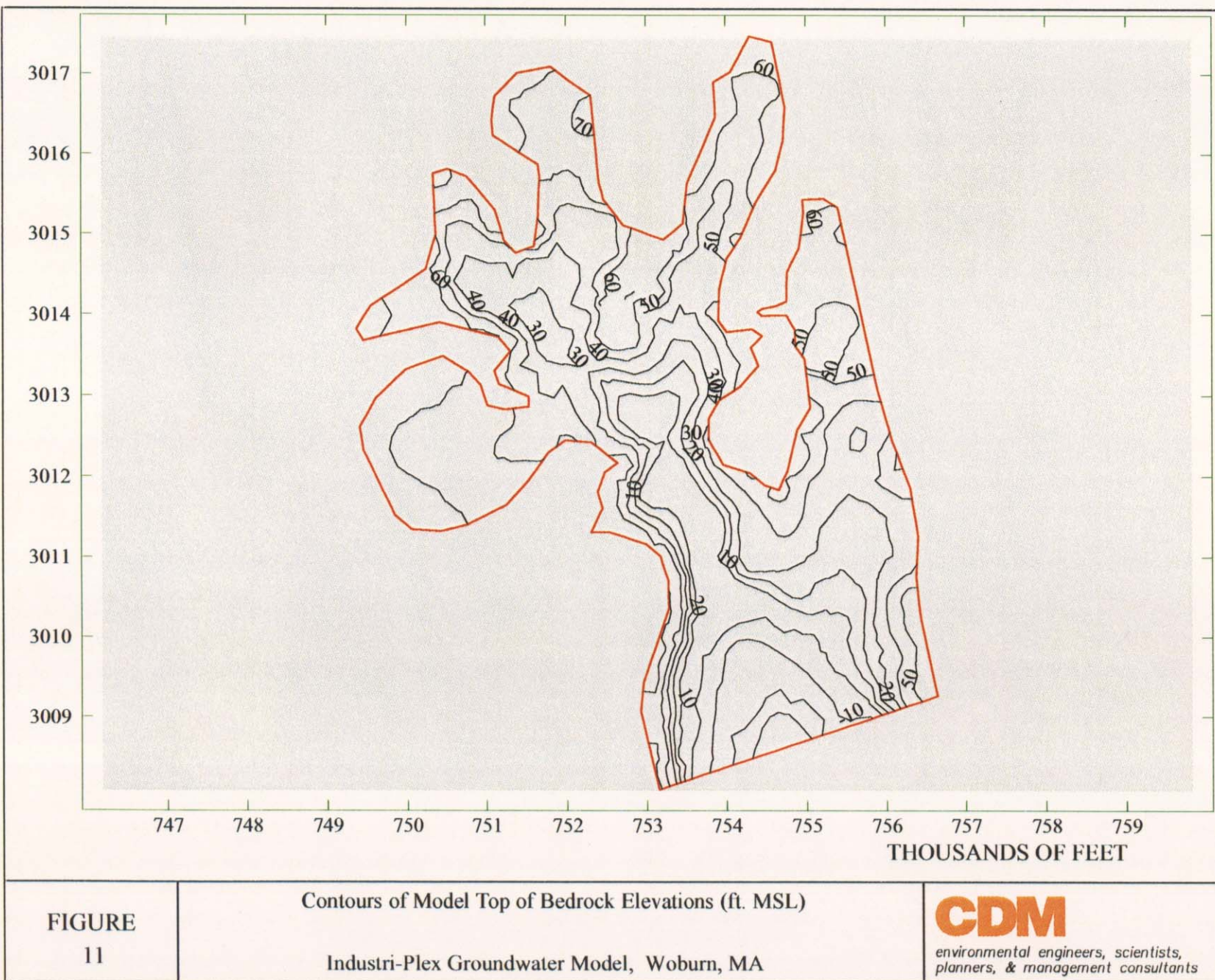


**FIGURE  
10**

**Model Structure Through Buried Valley**  
**Cross-Section AA**  
**Inustri-Plex Groundwater Model, Woburn, MA**

**CDM**

*environmental engineers, scientists,  
planners, & management consultants*



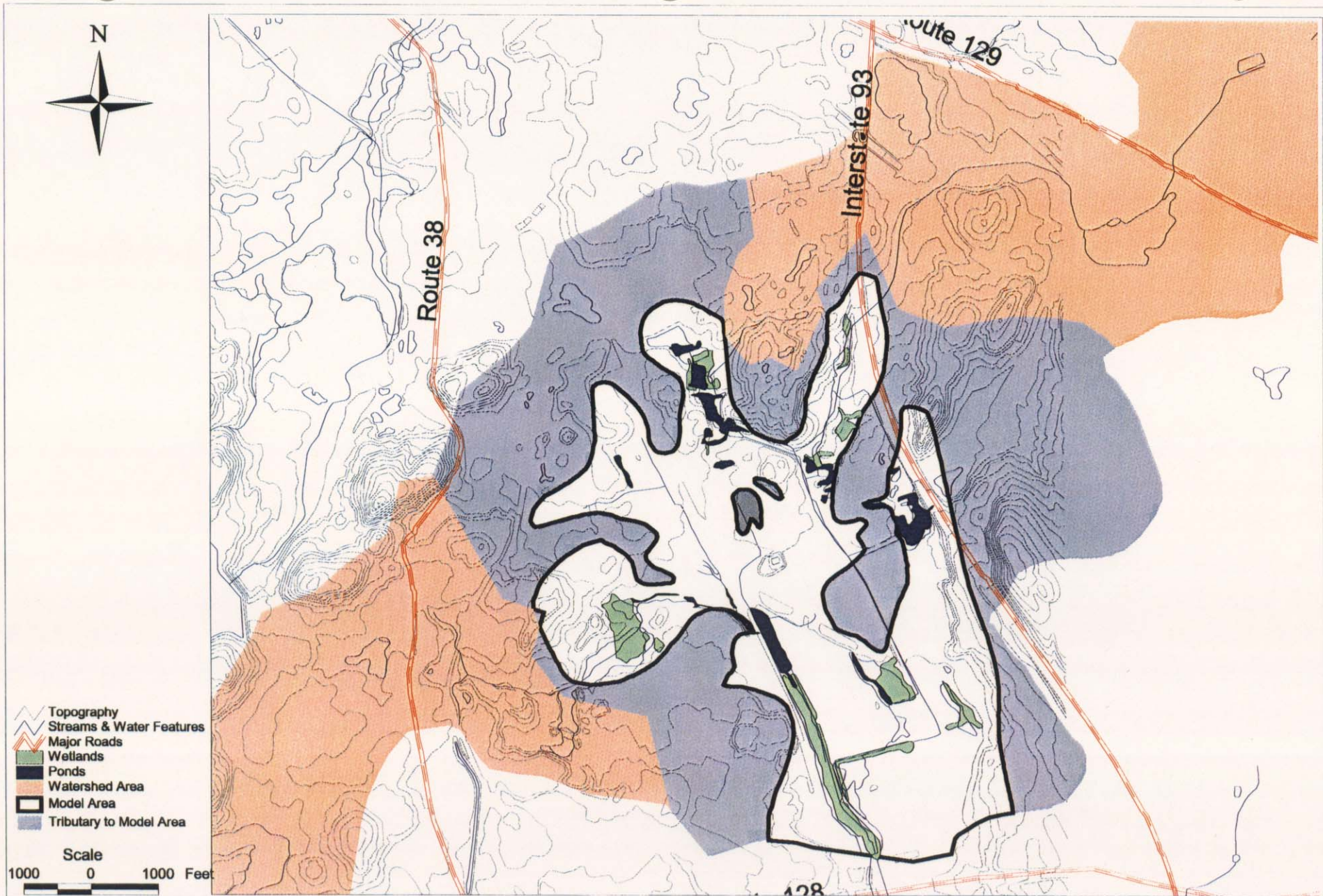


Figure 12: Watershed Areas

Industri-Plex Groundwater Model  
Woburn, Massachusetts

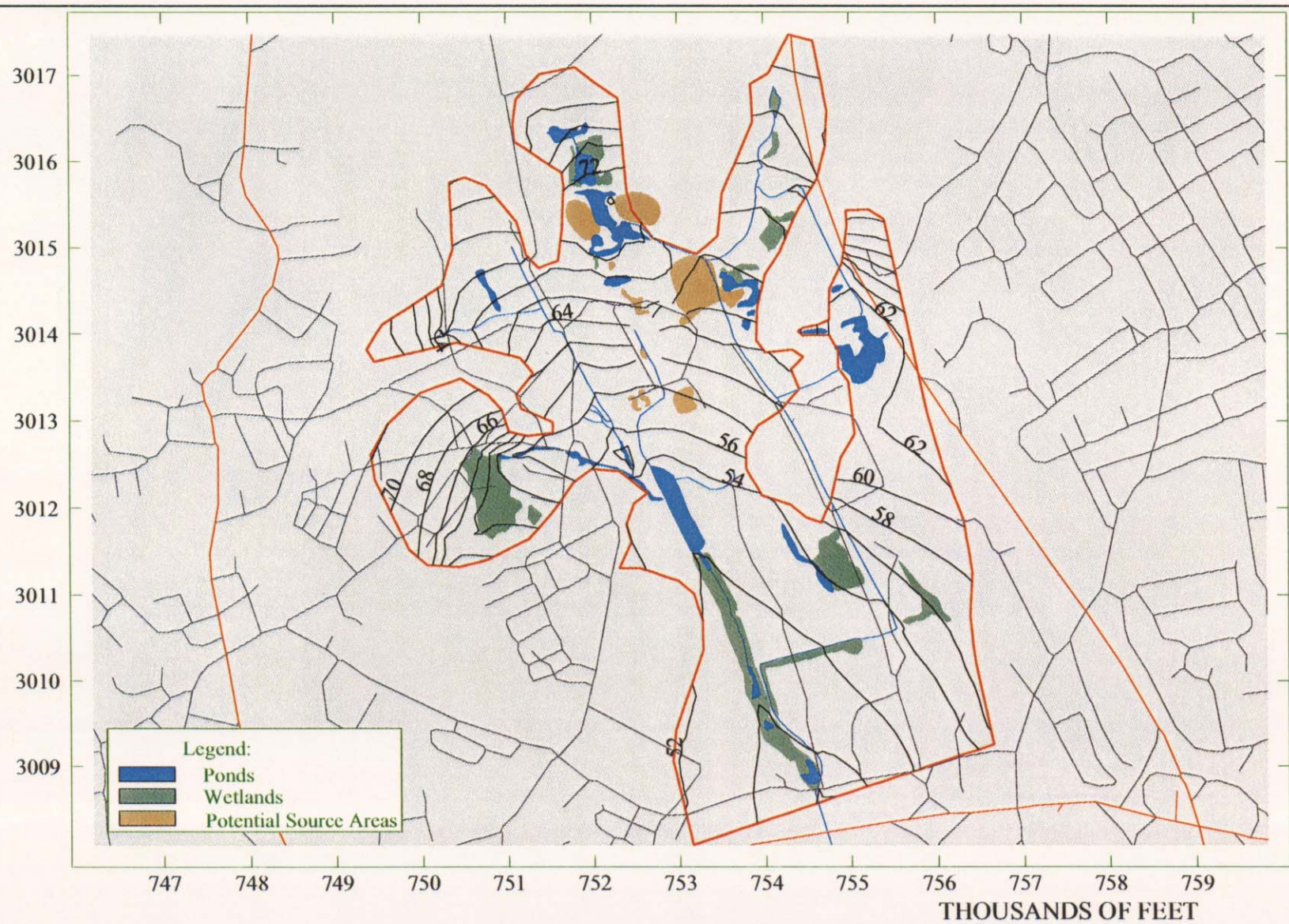


FIGURE  
13

Modeled Water Table Elevation Contours (Feet MSL)

Base Case  
Industri-Plex Groundwater Model, Woburn, MA

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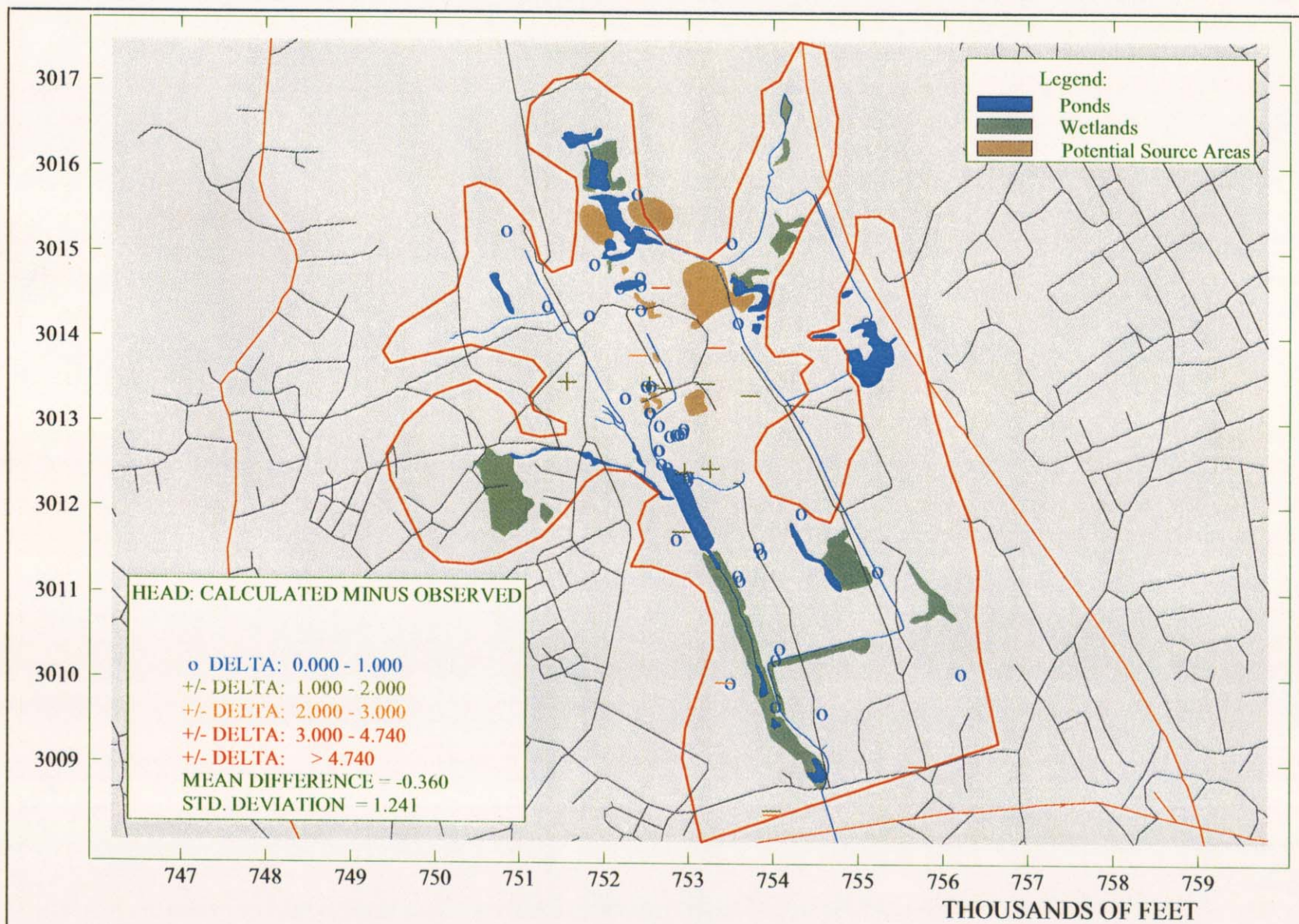
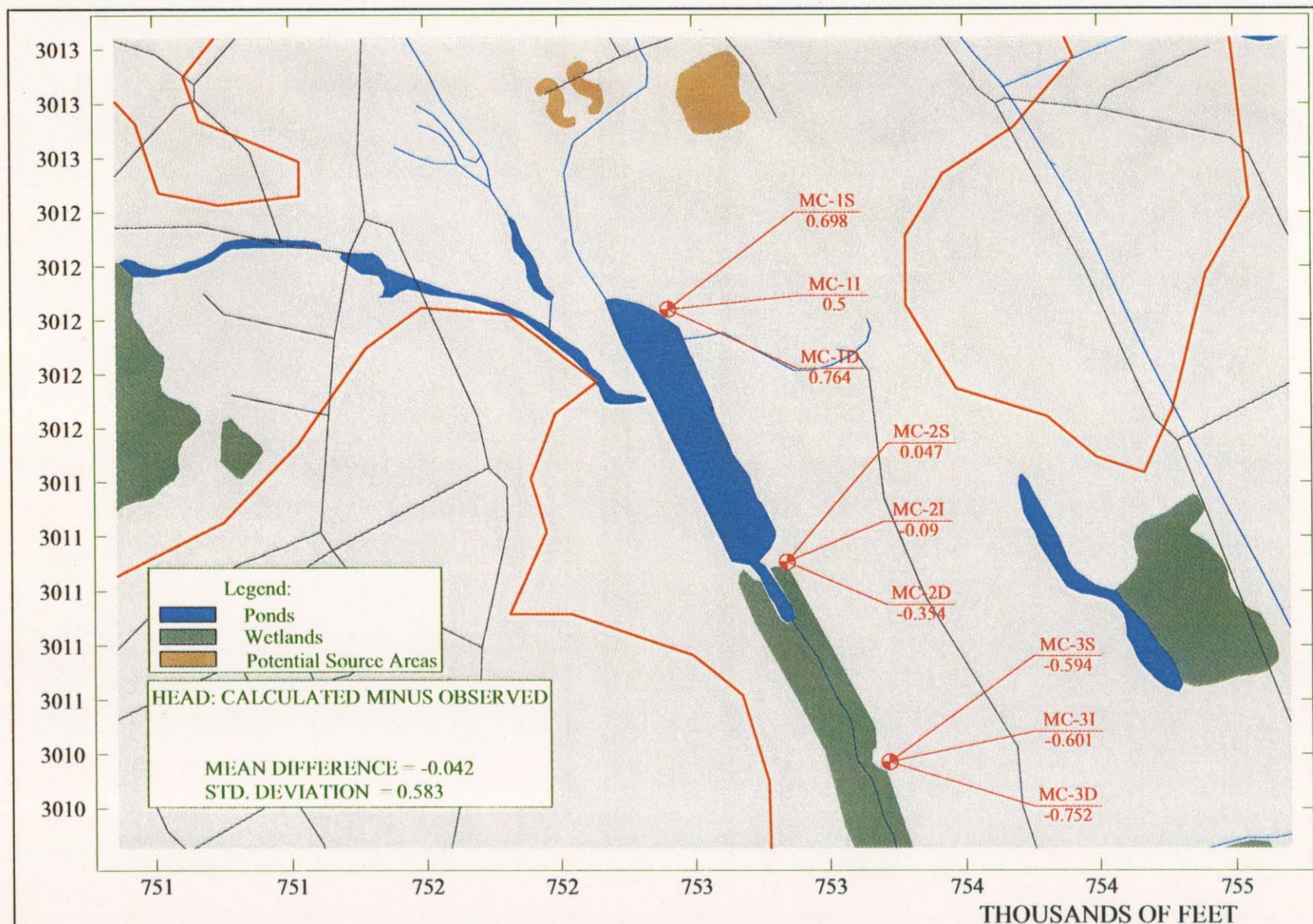


FIGURE  
14

Comparison of Observed and Modeled Heads  
"OW" Series Wells, Average 1990 - 1992 Measurements  
Base Case  
Industri-Plex Groundwater Model, Woburn, MA

**CDM**

environmental engineers, scientists,  
planners, & management consultants



**FIGURE**  
**15**

**Comparison of Observed and Modeled Heads**  
**Micro-Well Clusters, 1997 Measurements**  
**Base Case**  
**Industri-Plex Groundwater Model, Woburn, MA**

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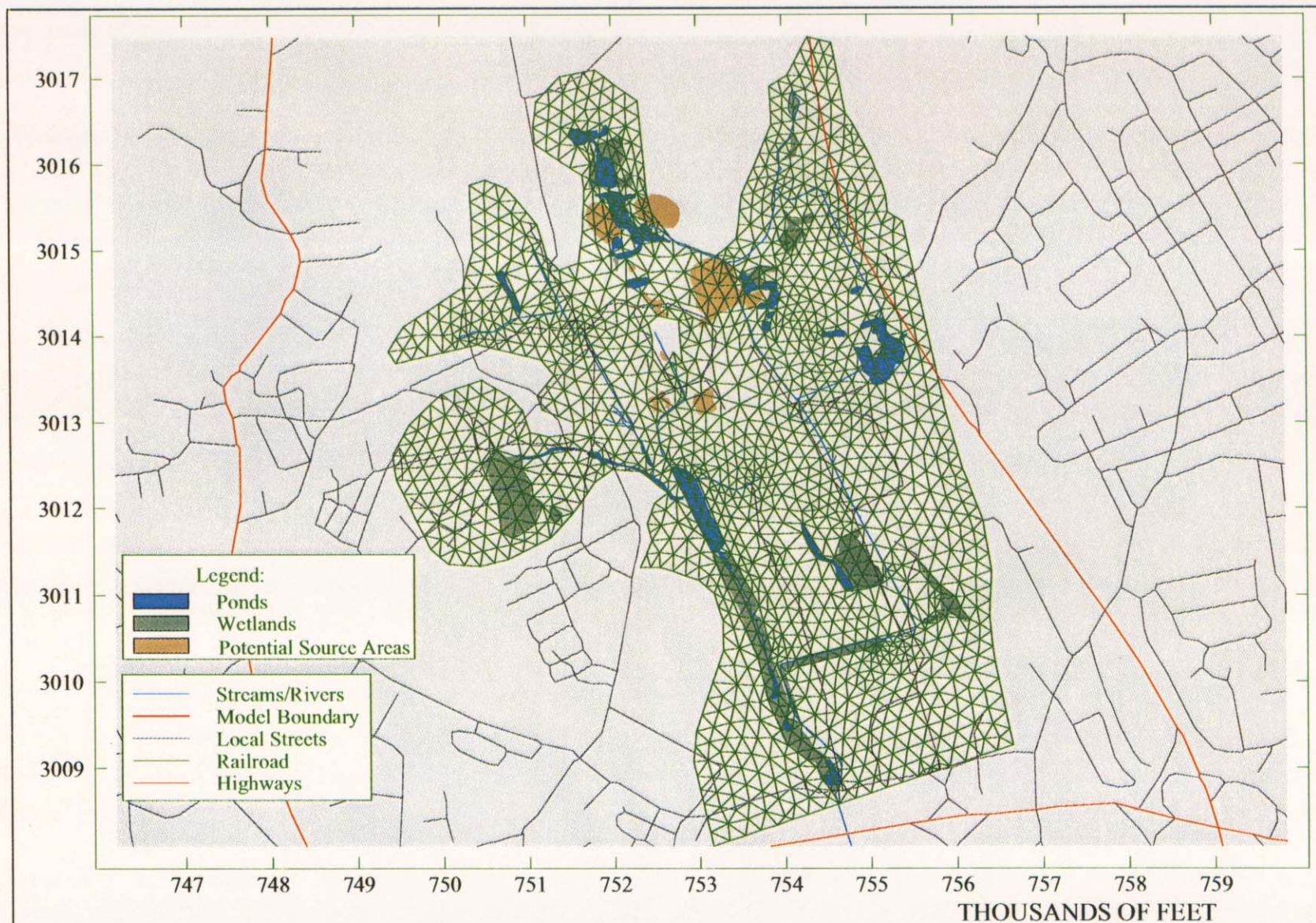
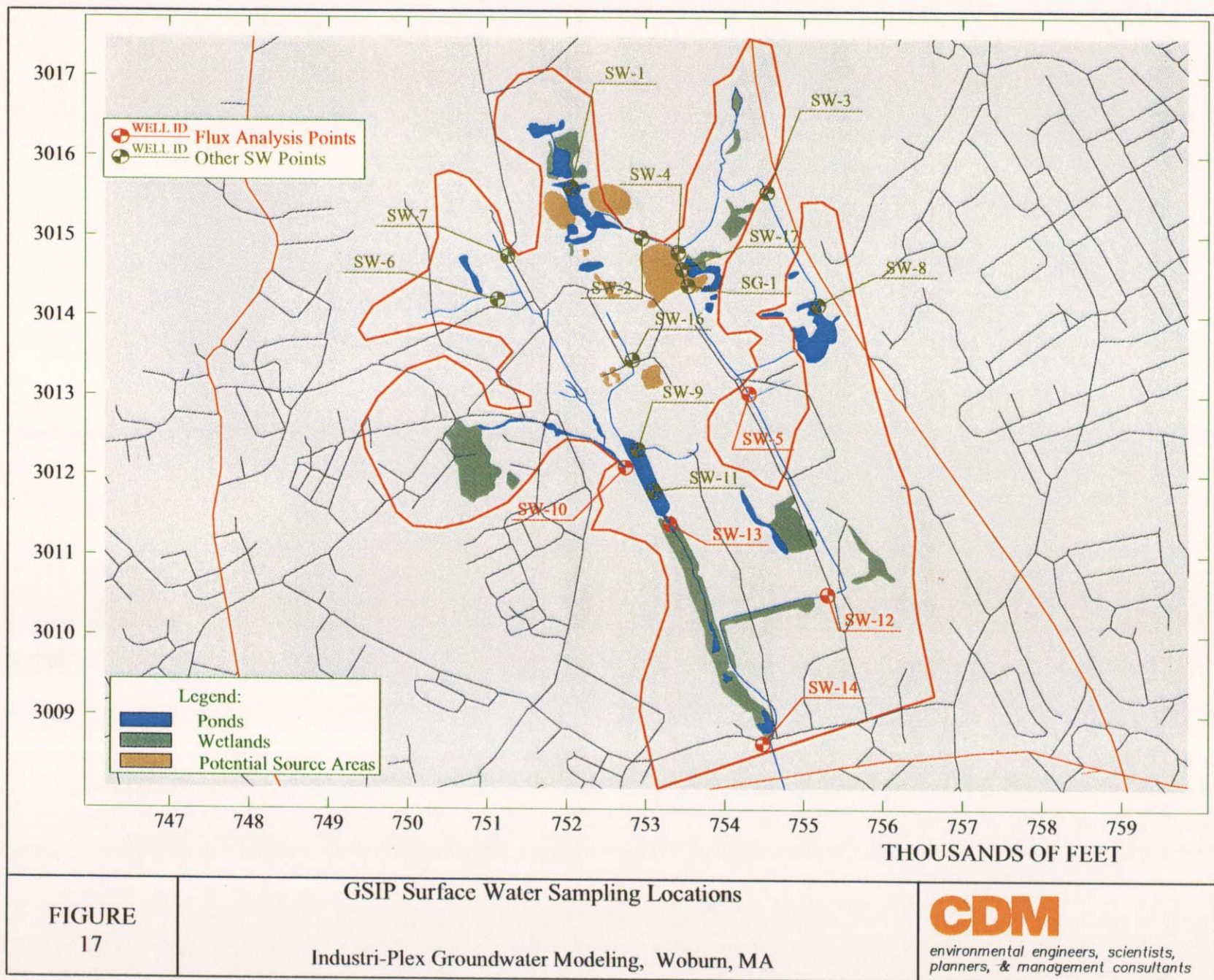


FIGURE  
16

Model Finite Element Grid  
Ecology and Environment Regional Bedrock Interpretation  
Industri-Plex Groundwater Model, Woburn, MA

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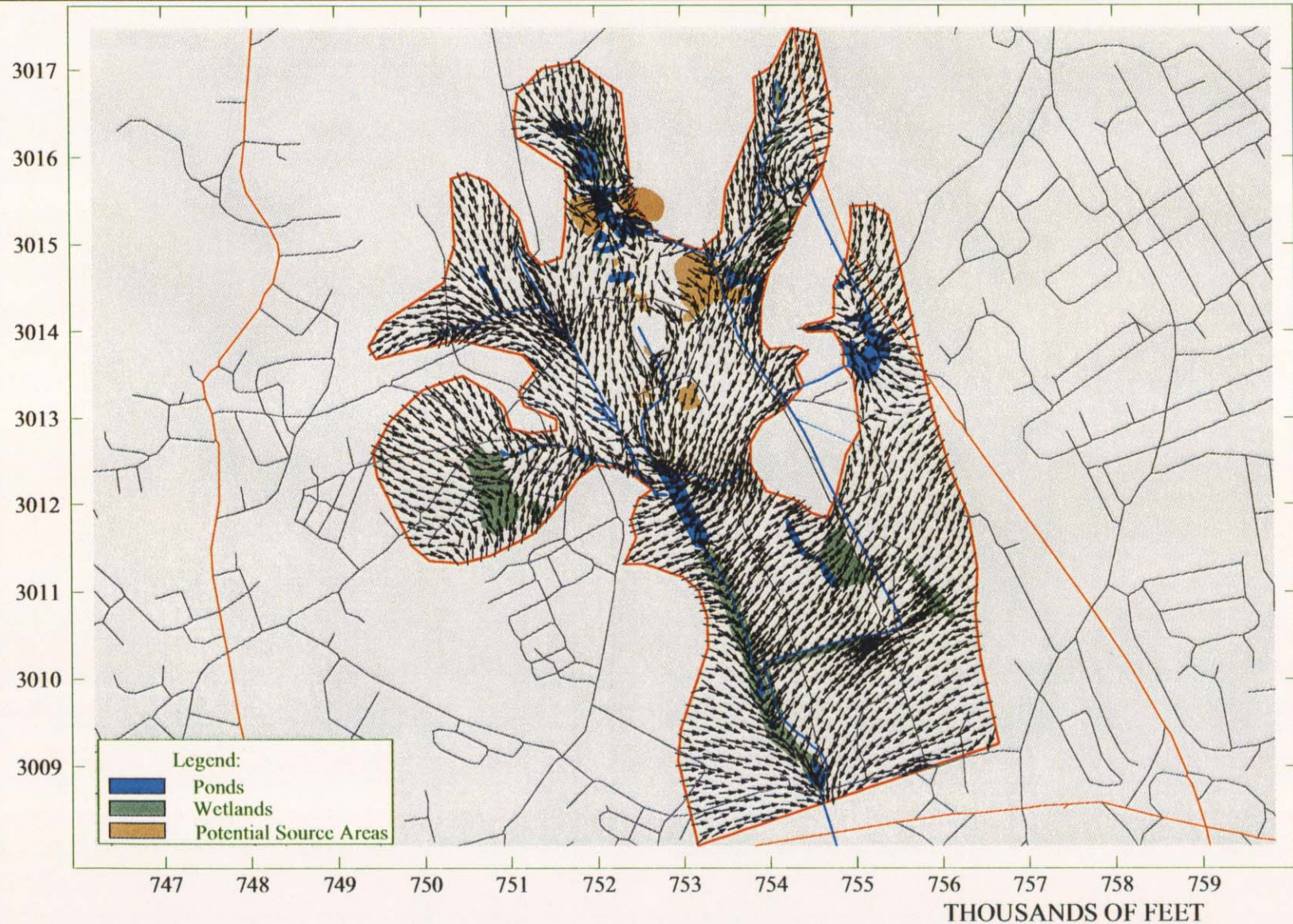
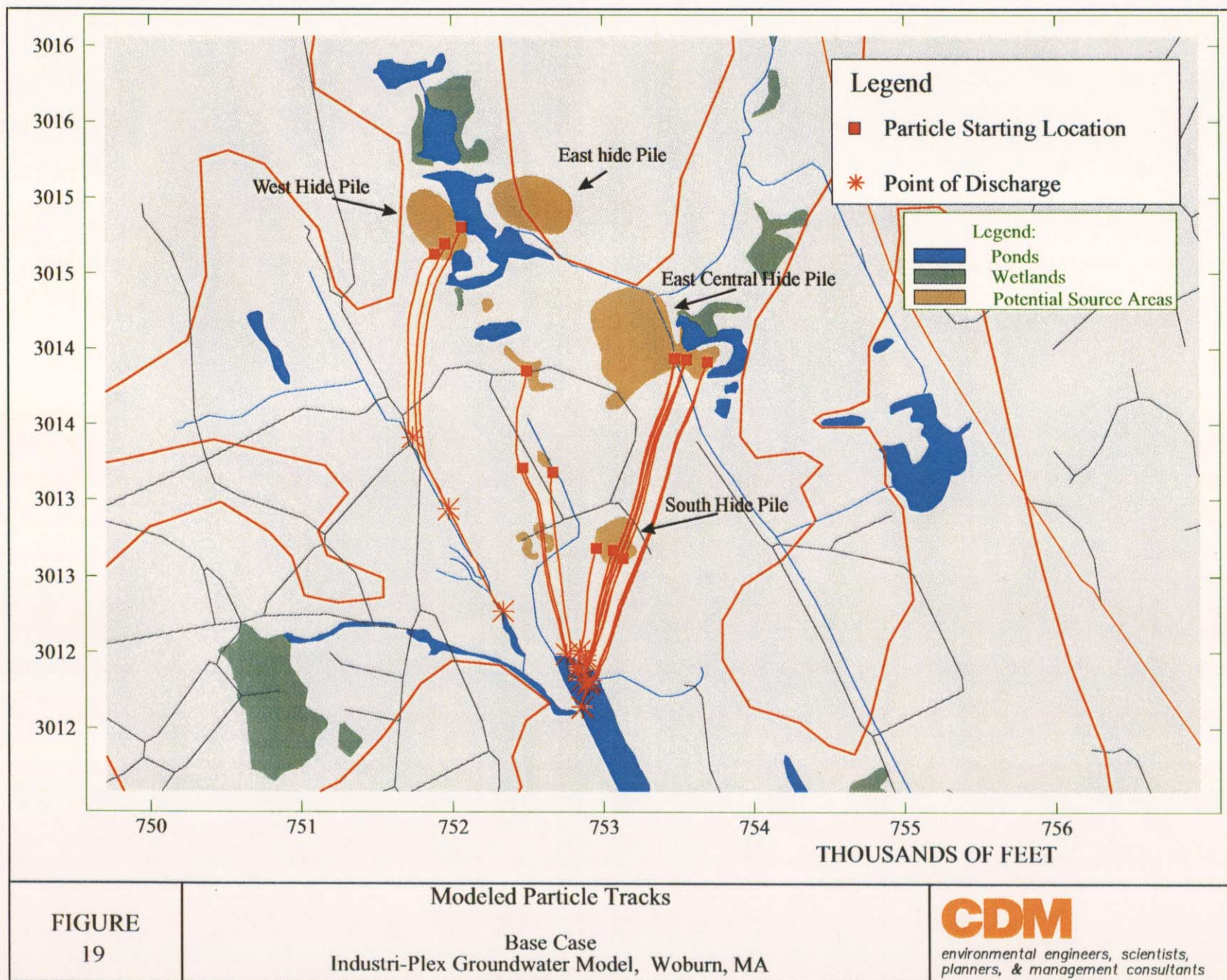
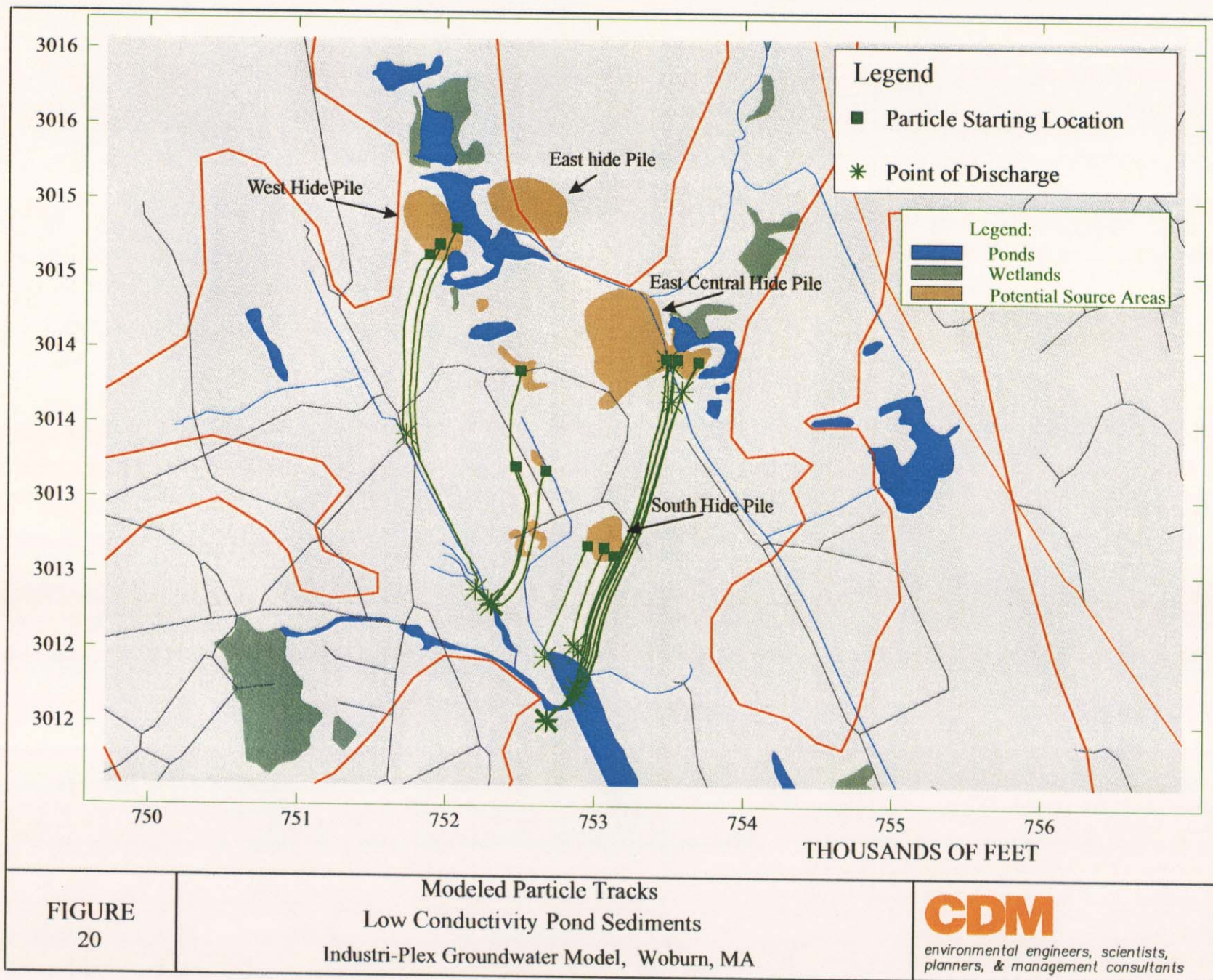


FIGURE  
18

Model Flow Direction Vectors  
Base Case  
Industri-Plex Groundwater Model, Woburn, MA

**CDM**  
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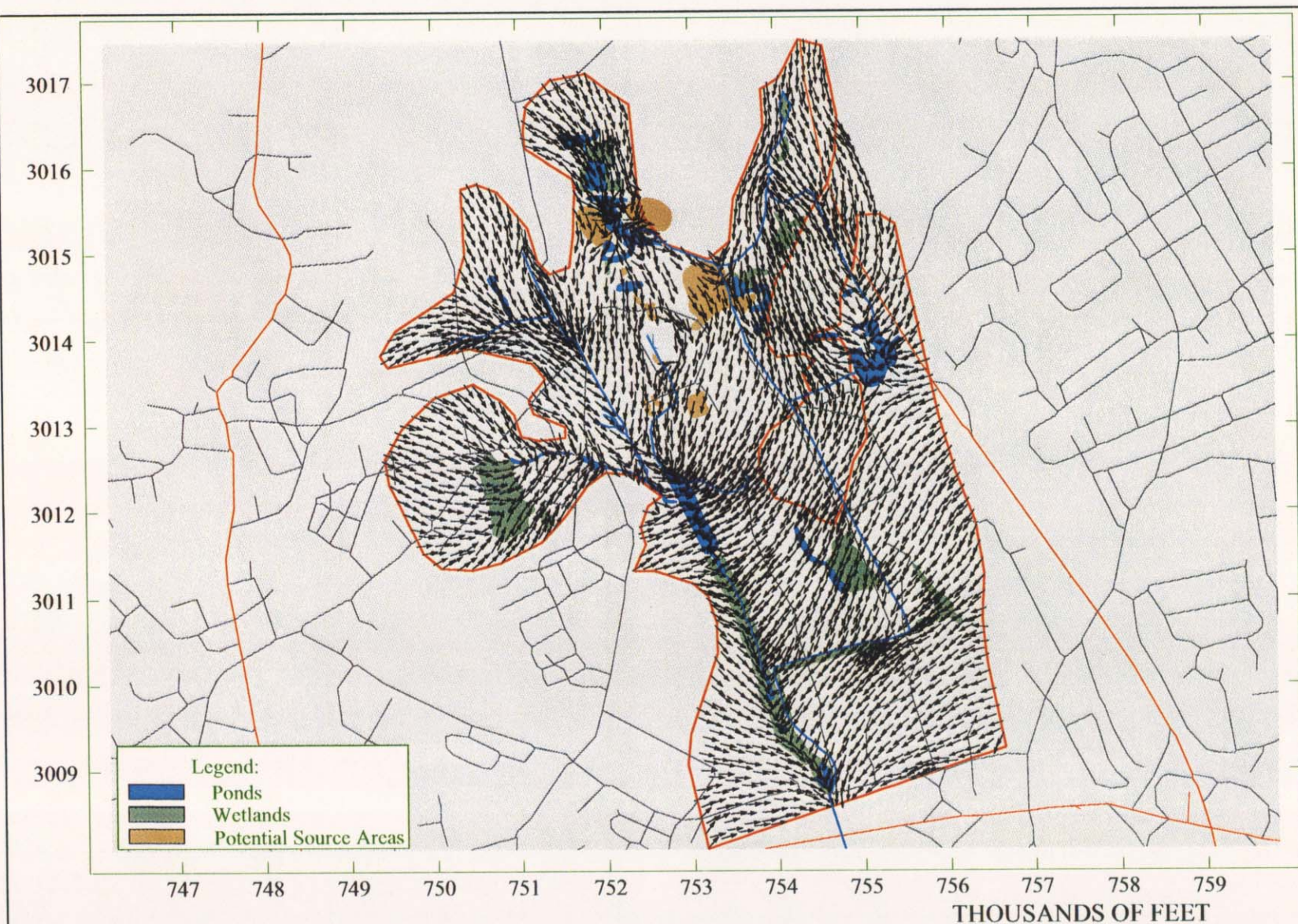


FIGURE  
21

Model Flow Direction Vectors  
 Ecology and Environment Regional Bedrock Interpretation  
 Industri-Plex Groundwater Model, Woburn, MA

**CDM**  
 environmental engineers, scientists,  
 planners, & management consultants

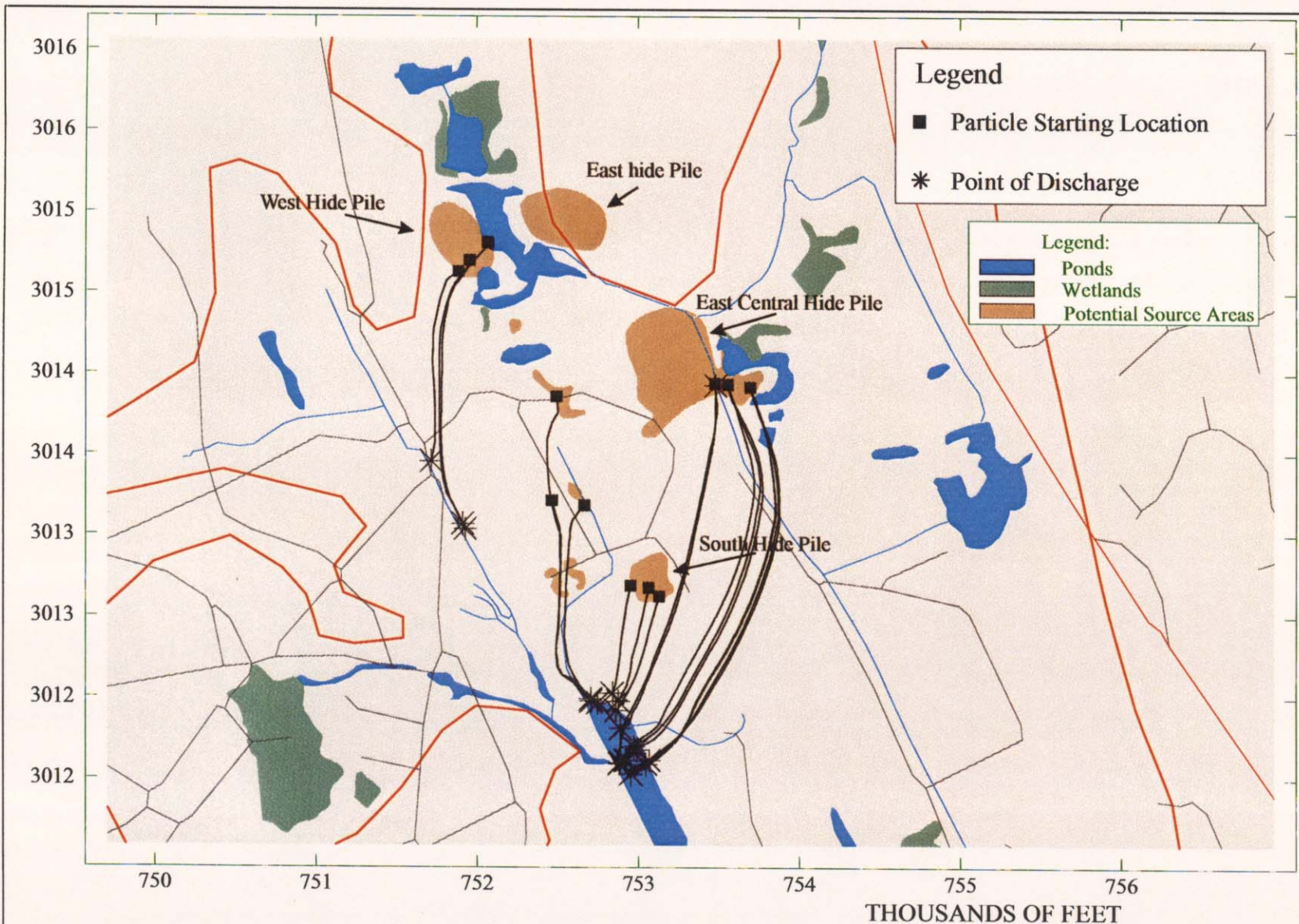
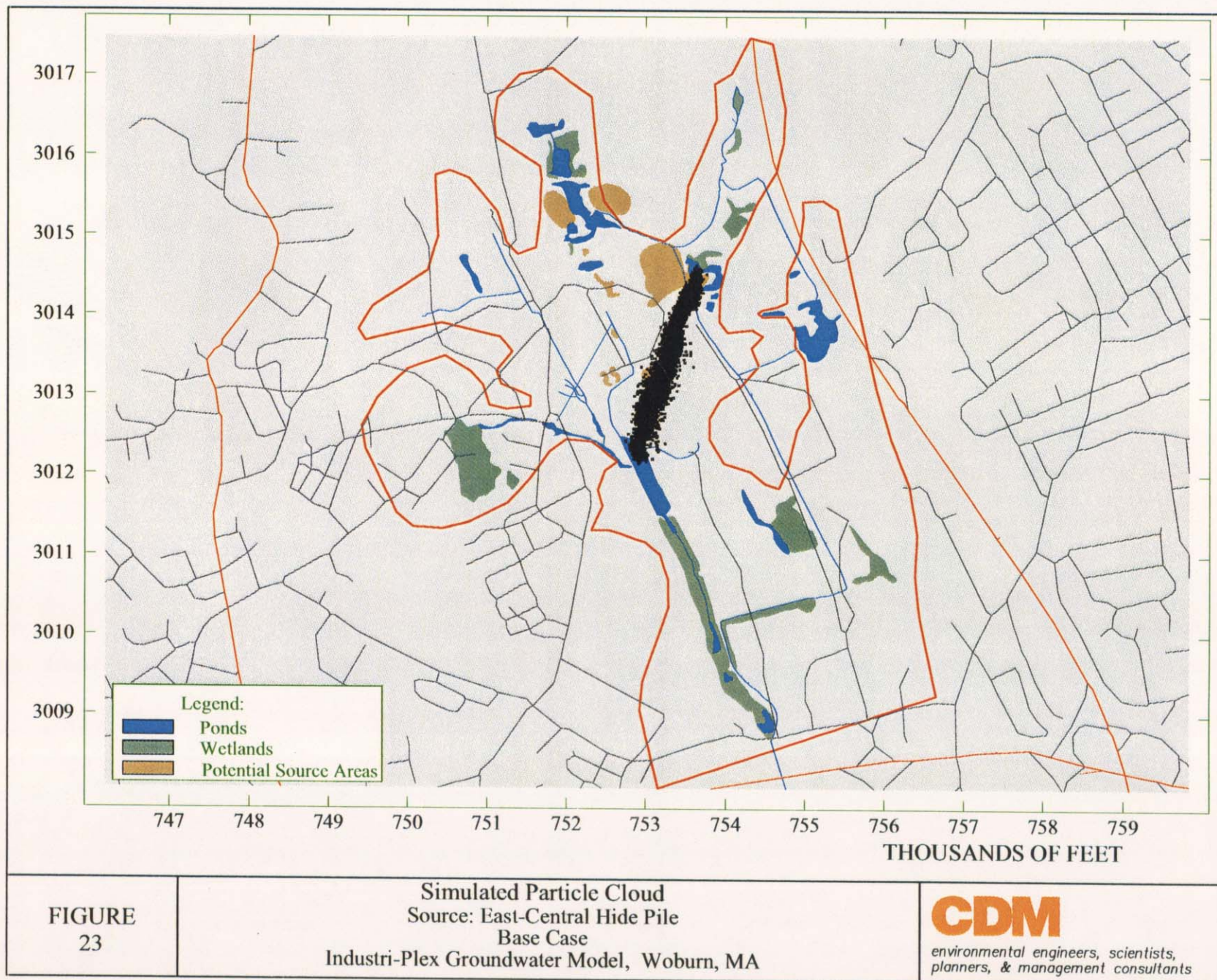


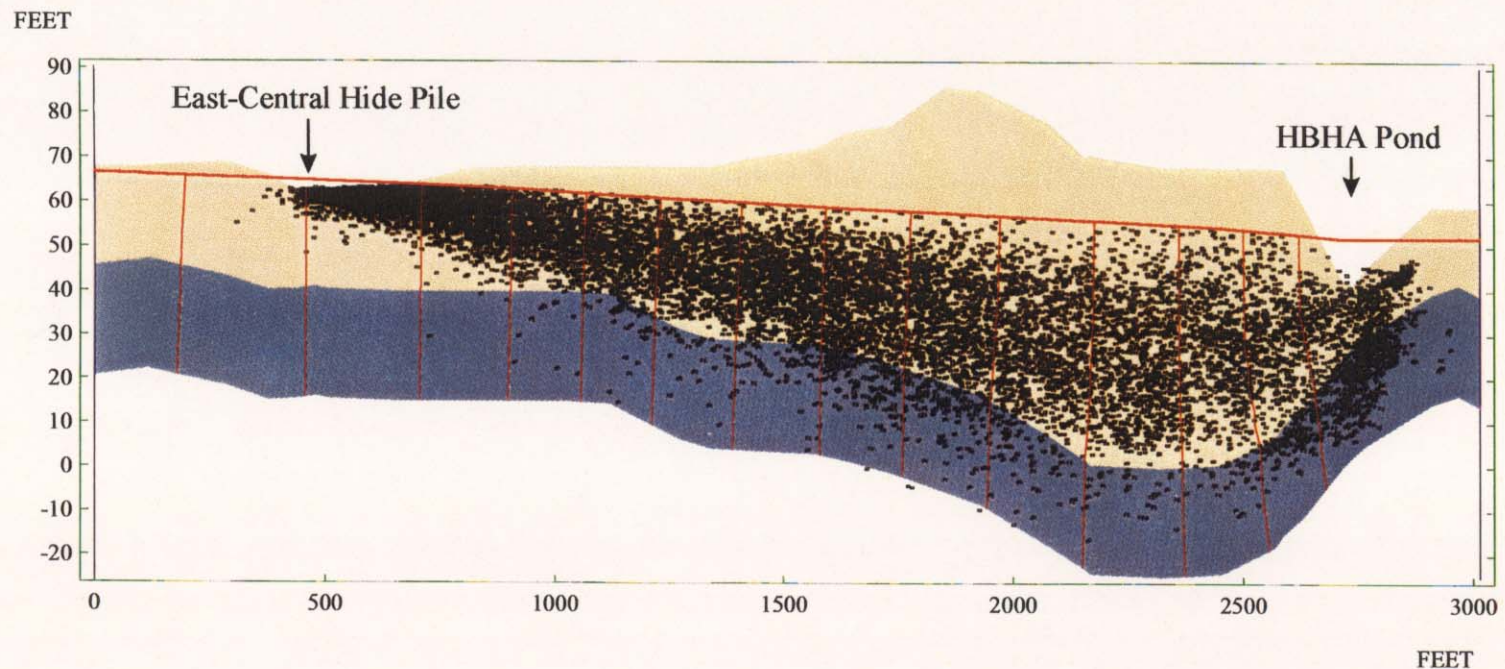
FIGURE  
22

Modeled Particle Tracks  
Ecology and Environment Regional Bedrock Interpretation  
Indusrti-Plex Groundwater Model, Woburn, MA

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CROSS SECTION BB

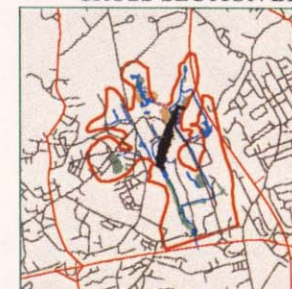
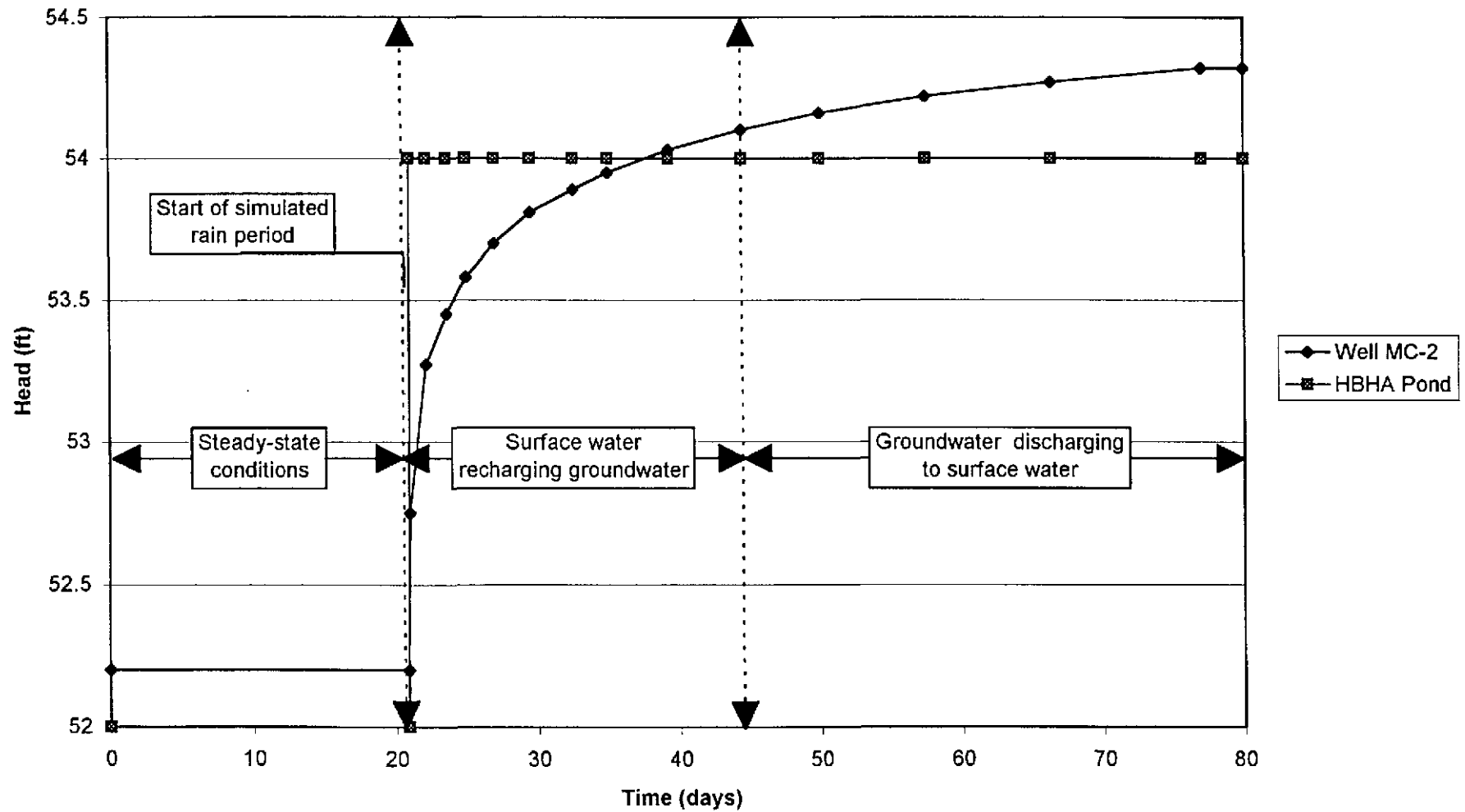


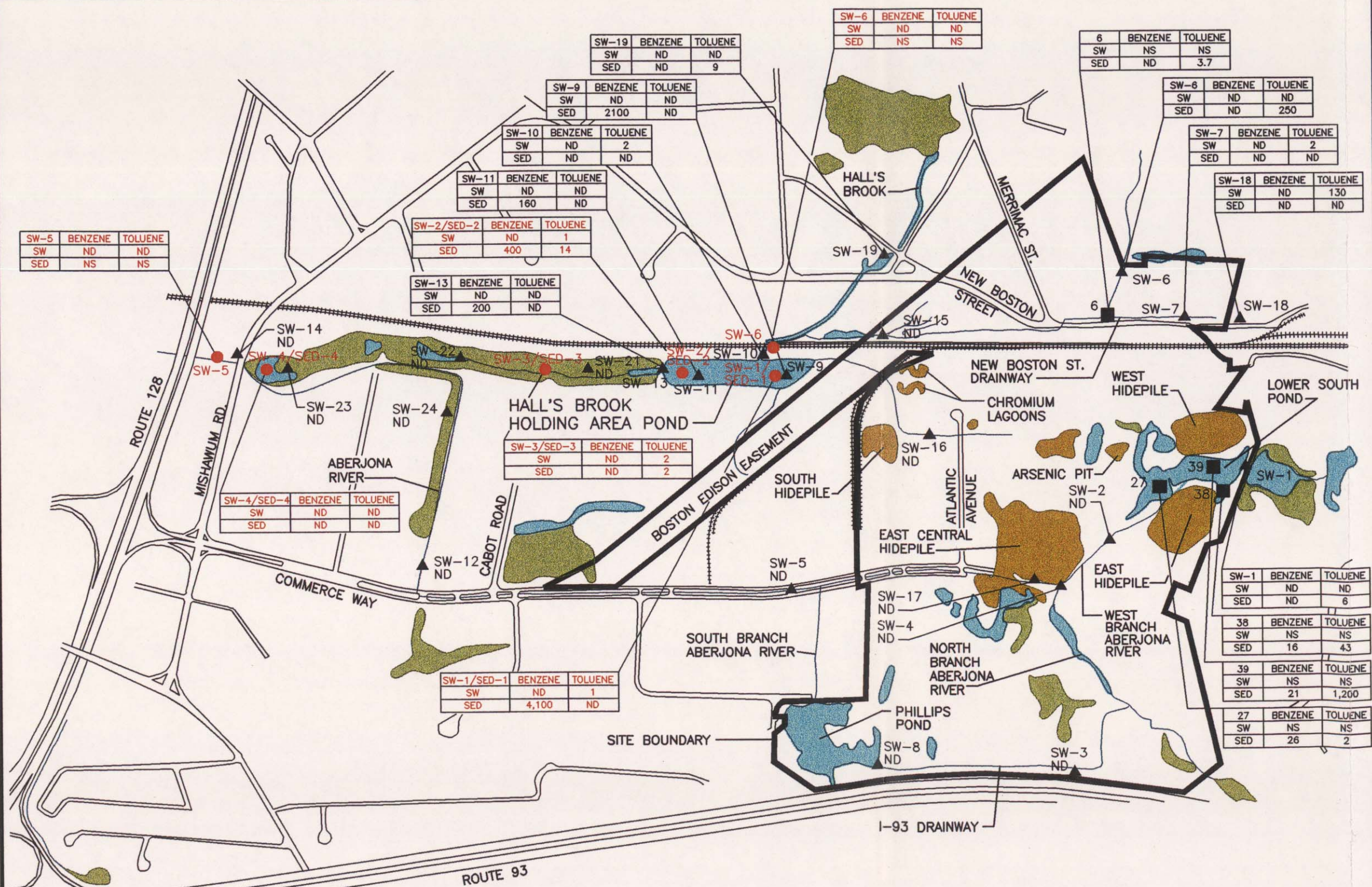
FIGURE  
24

Simulated Particle Cloud in Cross Section  
Base Case  
Industri-Plex Groundwater Model, Woburn, MA

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Figure 25:  
Time History of Modeled Heads at Micro-Cluster Well MC-2 and  
HBHA Pond During Simulated Period of Increased Rainfall





# LEGEND

CONCENTRATIONS OF BENZENE AND TOLUENE DETECTED IN SURFACE WATER, MEASURED IN MICROGRAMS PER LITER

SAMPLING LOCATION

SW-11	BENZENE	TOLUENE
SW	ND	ND
SED	200	ND

CONCENTRATIONS OF BENZENE AND TOLUENE DETECTED IN SEDIMENT, MEASURED IN MICROGRAMS PER KILOGRAM

NS NOT SAMPLED  
ND NOT DETECTED

SW-3 ▲ LOCATION AND DESIGNATION OF SURFACE-WATER/STREAM-SEDIMENT SAMPLE COLLECTED DURING GSIP

SW-4/SED-4 ● LOCATION AND DESIGNATION OF SURFACE-WATER/STREAM-SEDIMENT SAMPLE COLLECTED DURING SSI

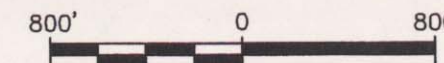
6 ■ LOCATION AND DESIGNATION OF SEDIMENT SAMPLE COLLECTED DURING PDI

● POTENTIAL SOURCE AREAS

● WETLANDS

● SURFACE WATER BODIES

NOTE: SSI SAMPLING LOCATIONS SW/SED-1 AND SW/SED-2, ONLY THE DATA FOR SHALLOW SURFACE WATER AND SURFICIAL SEDIMENT ARE SHOWN



Title:

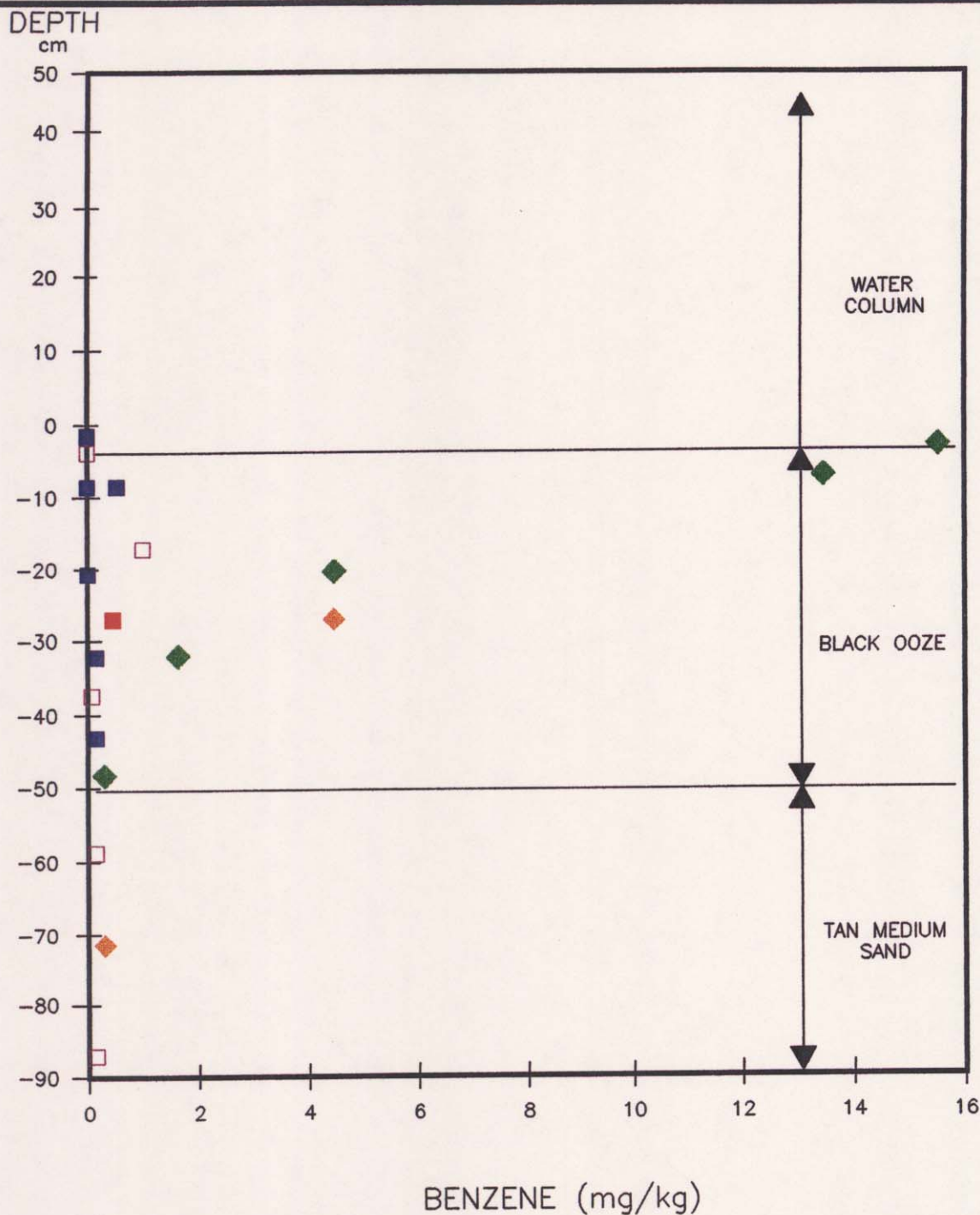
## BENZENE AND TOLUENE IN SURFACE WATER AND SEDIMENT

SUPPLEMENTAL SITE INVESTIGATION

Prepared For:  
INDUSTRI-PLEX SITE REMEDIAL TRUST

**ROUX**  
ROUX ASSOCIATES INC  
Environmental Consulting  
& Management

Compiled by: L.M.	Date: 9/97	FIGURE 26
Prepared by: G.M.	Scale: AS SHOWN	
Project Mgr: L.M.	Status: FINAL	
File No: M2610612	Project: 06626M10	



### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## BENZENE IN BULK SEDIMENTS (mg/kg)

### SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

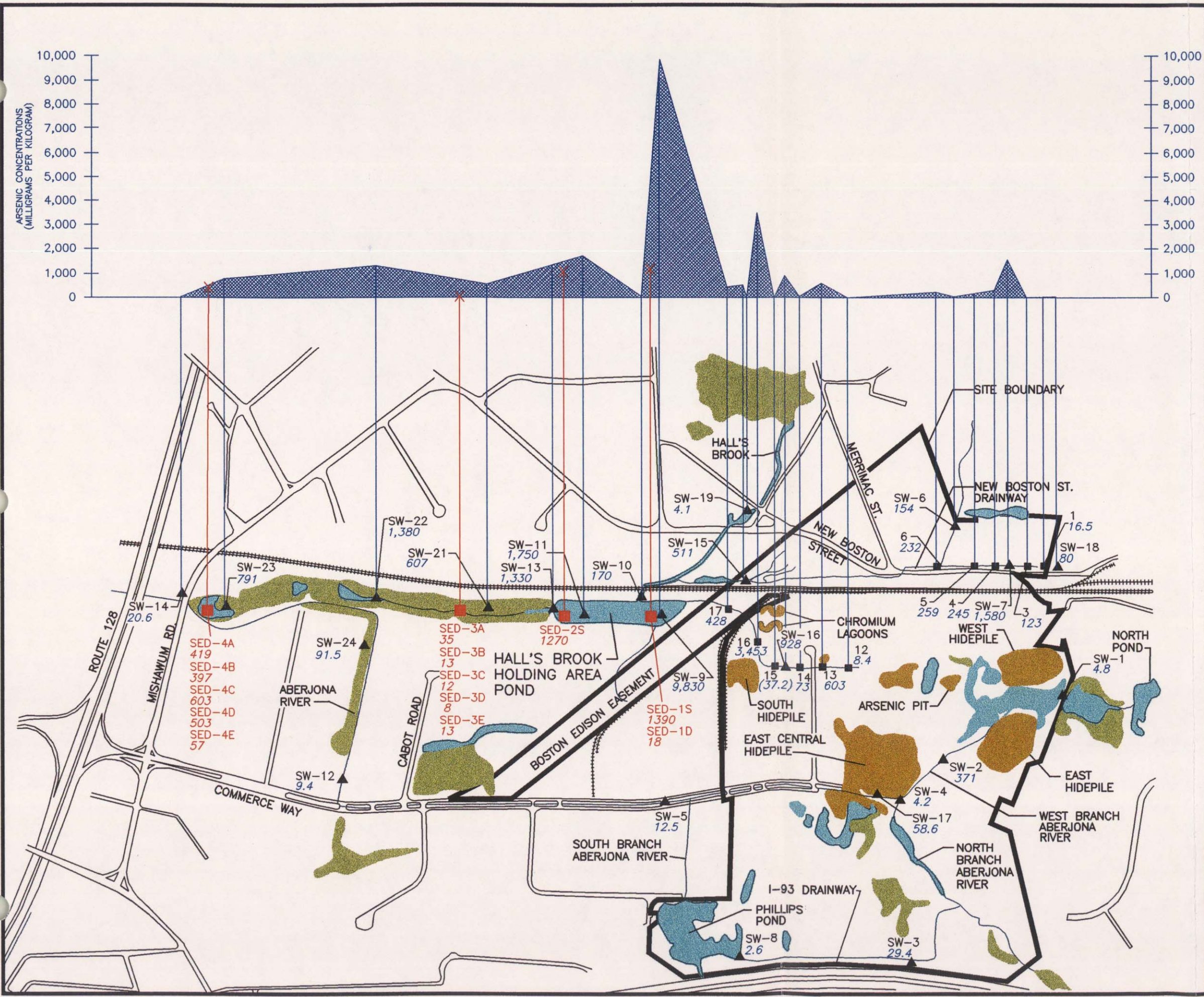
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Environmental Consulting  
& Management

Compiled by: S.W.	Date: 9/97
Prepared by: G.M.	Scale: As Shown
Project Mgr: D.S.	Status: FINAL
File No: M2610601	Project: 06626M10

FIGURE

27



EXPLANATION

- SW-3 ▲ GSI STREAM-SEDIMENT SAMPLE LOCATION AND DESIGNATION
- 4 ■ PRE-DESIGN INVESTIGATION STREAM-SEDIMENT SAMPLING LOCATION AND DESIGNATION
- 245 — CONCENTRATION OF ARSENIC DETECTED IN SEDIMENT, MEASURED IN MILLIGRAMS PER KILOGRAM
- SW-3A ■ SSI STREAM-SEDIMENT SAMPLE LOCATION AND DESIGNATION
- 35 — CONCENTRATION OF ARSENIC DETECTED IN STREAM SEDIMENT, MEASURED IN MILLIGRAMS PER KILOGRAM
- POTENTIAL SOURCE AREA
- WETLANDS
- SURFACE WATER BODIES

NOTE: 1. ARSENIC CONCENTRATIONS IN ABERJONA RIVER SEDIMENTS UPSTREAM OF MISHAWUM ROAD ARE CONSISTENTLY LOW, AND ARE THEREFORE NOT INCLUDED IN GRAPH.

2. Xs INDICATE CONCENTRATION OF ARSENIC IN STREAM SEDIMENT DURING SSI

Title: CONCENTRATIONS OF ARSENIC DETECTED IN STREAM SEDIMENTS

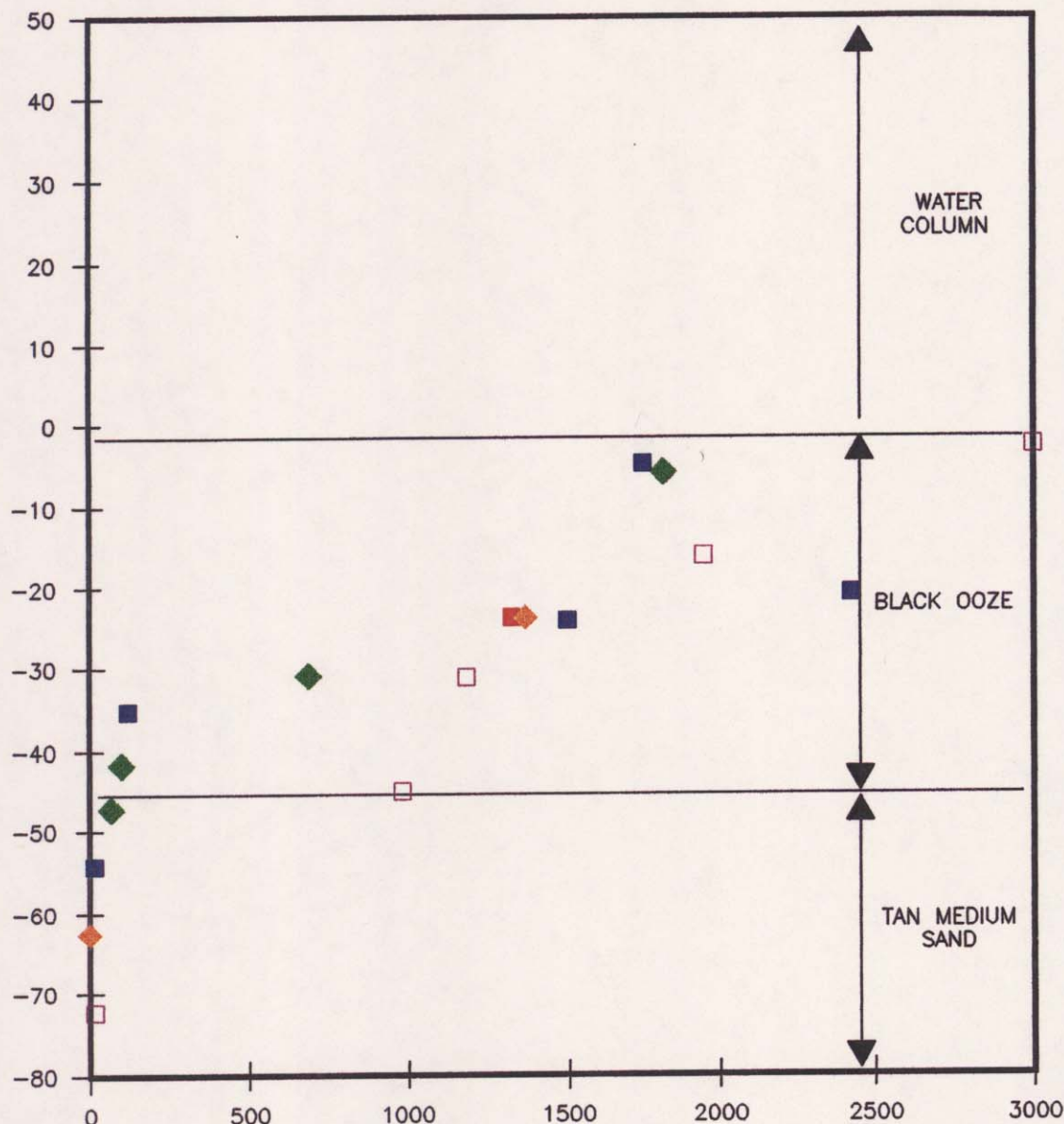
SUPPLEMENTAL SITE INVESTIGATION

Prepared For: INDUSTRI-PLEX SITE REMEDIAL TRUST

ROUX ASSOCIATES INC. Environmental Consulting & Management

Compiled by: S.W.	Date: 9/97	FIGURE 28
Prepared by: G.M.	Scale: AS SHOWN	
Project Mgr: L.M.	Status: FINAL	
File No: M2610613	Project: 06626M10	

DEPTH  
cm



ARSENIC (mg/kg)

### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## ARSENIC IN BULK SEDIMENTS (mg/kg)

SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

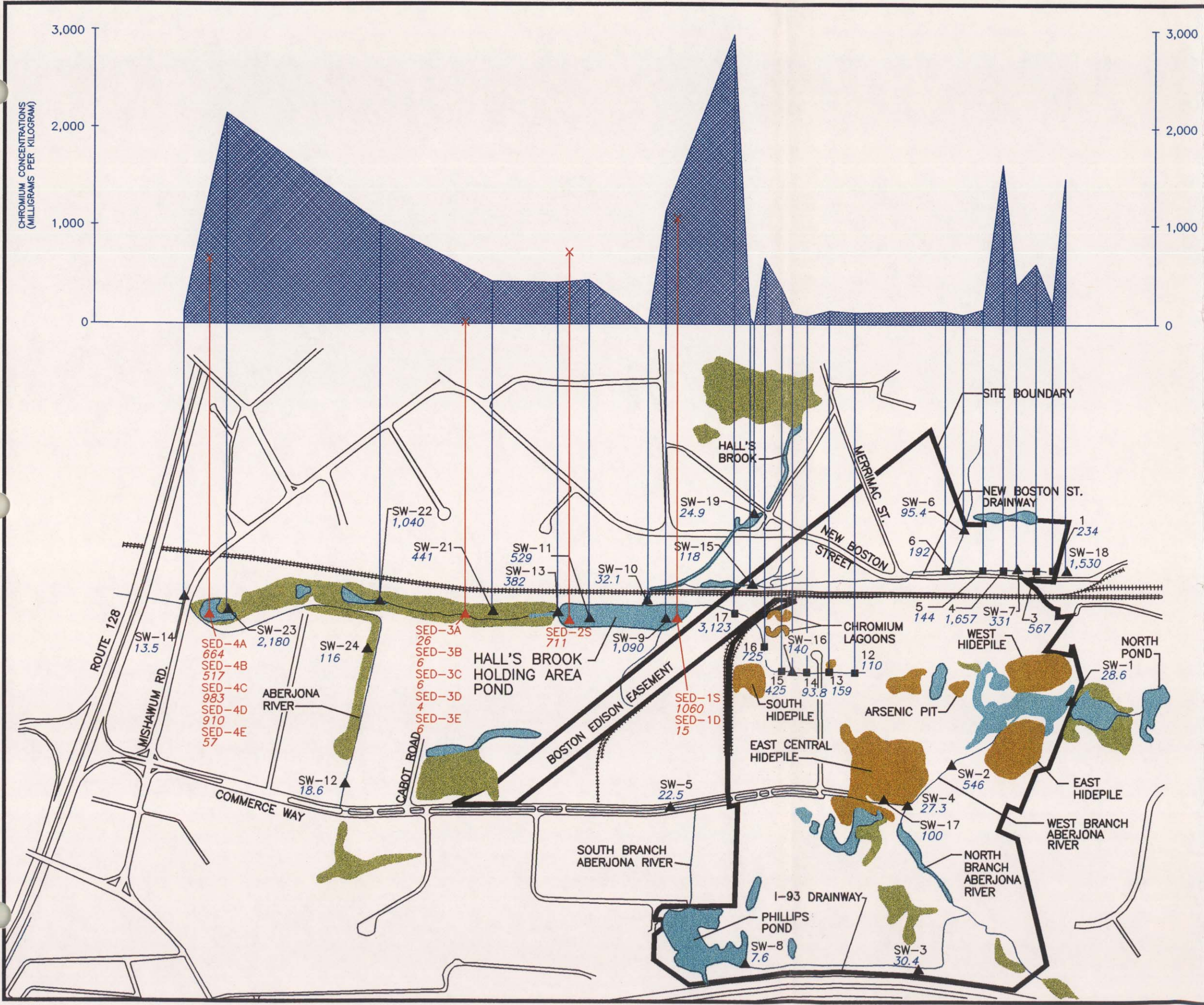
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Environmental Consulting  
& Management

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Prepared by: G.M.	Scale: As Shown
Project Mgr: D.S.	Status: FINAL
File No: M2610602	Project: 06626M10

FIGURE

29



EXPLANATION

- SW-3 ■ GSIP STREAM-SEDIMENT SAMPLE LOCATION AND DESIGNATION
- 5 ■ PRE-DESIGN INVESTIGATION STREAM-SEDIMENT SAMPLING LOCATION AND DESIGNATION
- 1,657 CONCENTRATION OF CHROMIUM DETECTED IN STREAM-SEDIMENT, MEASURED IN MILLIGRAMS PER KILOGRAM
- SED-3A ▲ SSI STREAM-SEDIMENT SAMPLE LOCATION AND DESIGNATION
- 26 CONCENTRATION OF CHROMIUM DETECTED IN STREAM-SEDIMENT, MEASURED IN MILLIGRAMS PER KILOGRAM
- POTENTIAL SOURCE AREA
- WETLANDS
- SURFACE WATER BODIES

NOTE: 1. CHROMIUM CONCENTRATIONS IN ABERJONA RIVER SEDIMENTS UPSTREAM OF MISHAWUM ROAD ARE CONSISTENTLY LOW, AND ARE THEREFORE NOT INCLUDED IN GRAPH.

2. Xs INDICATE CONCENTRATION OF CHROMIUM IN STREAM SEDIMENT DURING SSI

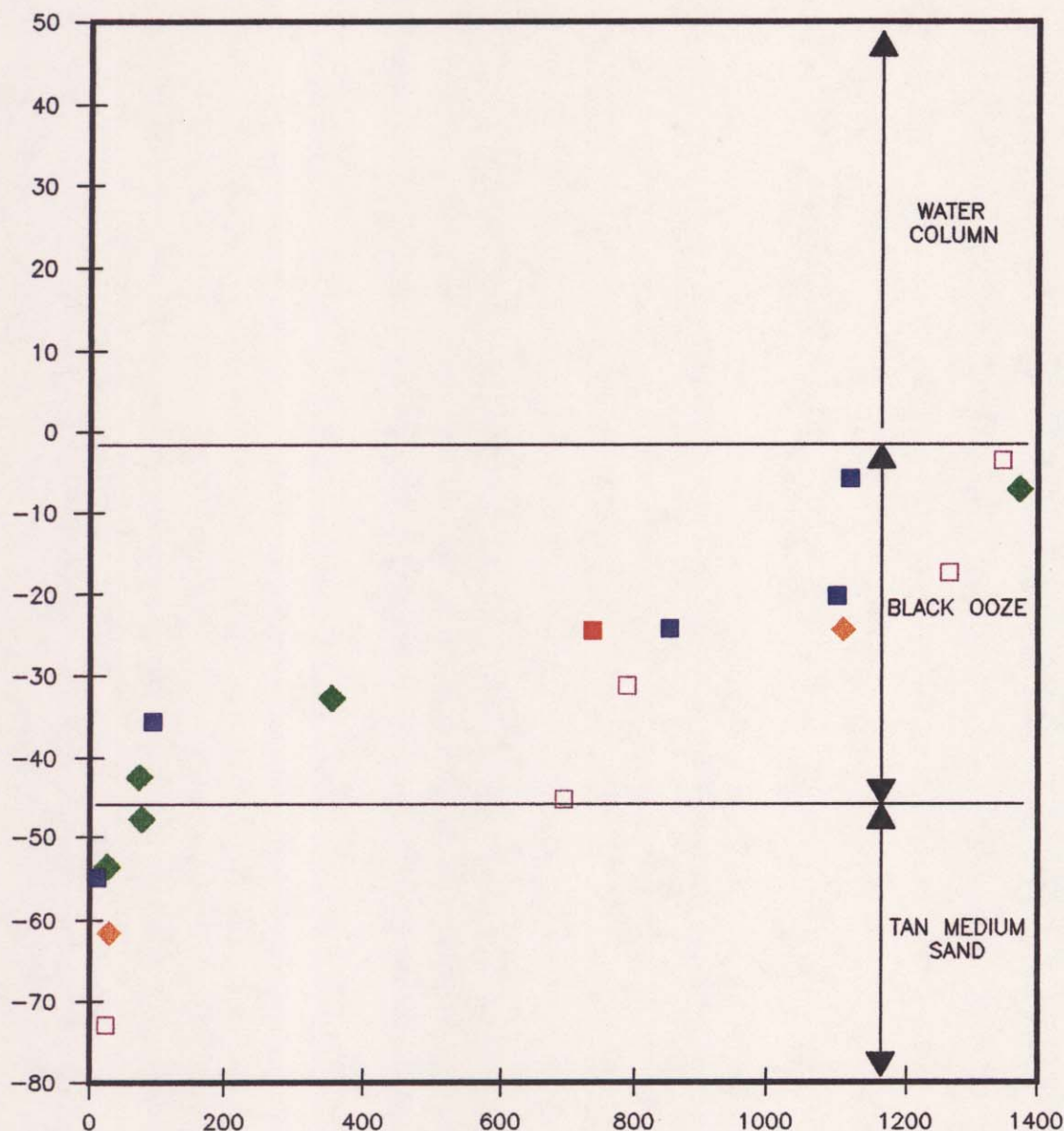
Title: CONCENTRATIONS OF CHROMIUM DETECTED IN STREAM SEDIMENTS

SUPPLEMENTAL SITE INVESTIGATION

Prepared For: INDUSTRI-PLEX SITE REMEDIAL TRUST

ROUX ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: S.W.	Date: 9/97	FIGURE 30
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610614	Project: 06626M10	

DEPTH  
cm



CHROMIUM (mg/kg)

### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## TOTAL CHROMIUM IN BULK SEDIMENTS (mg/kg)

### SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

INDUSTRI-PLEX SITE REMEDIAL TRUST

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Environmental Consulting  
& Management

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Prepared by: G.M.	Scale: As Shown
Project Mgr: L.M.	Status: FINAL
File No: M2610603	Project: 06626M10

FIGURE

31

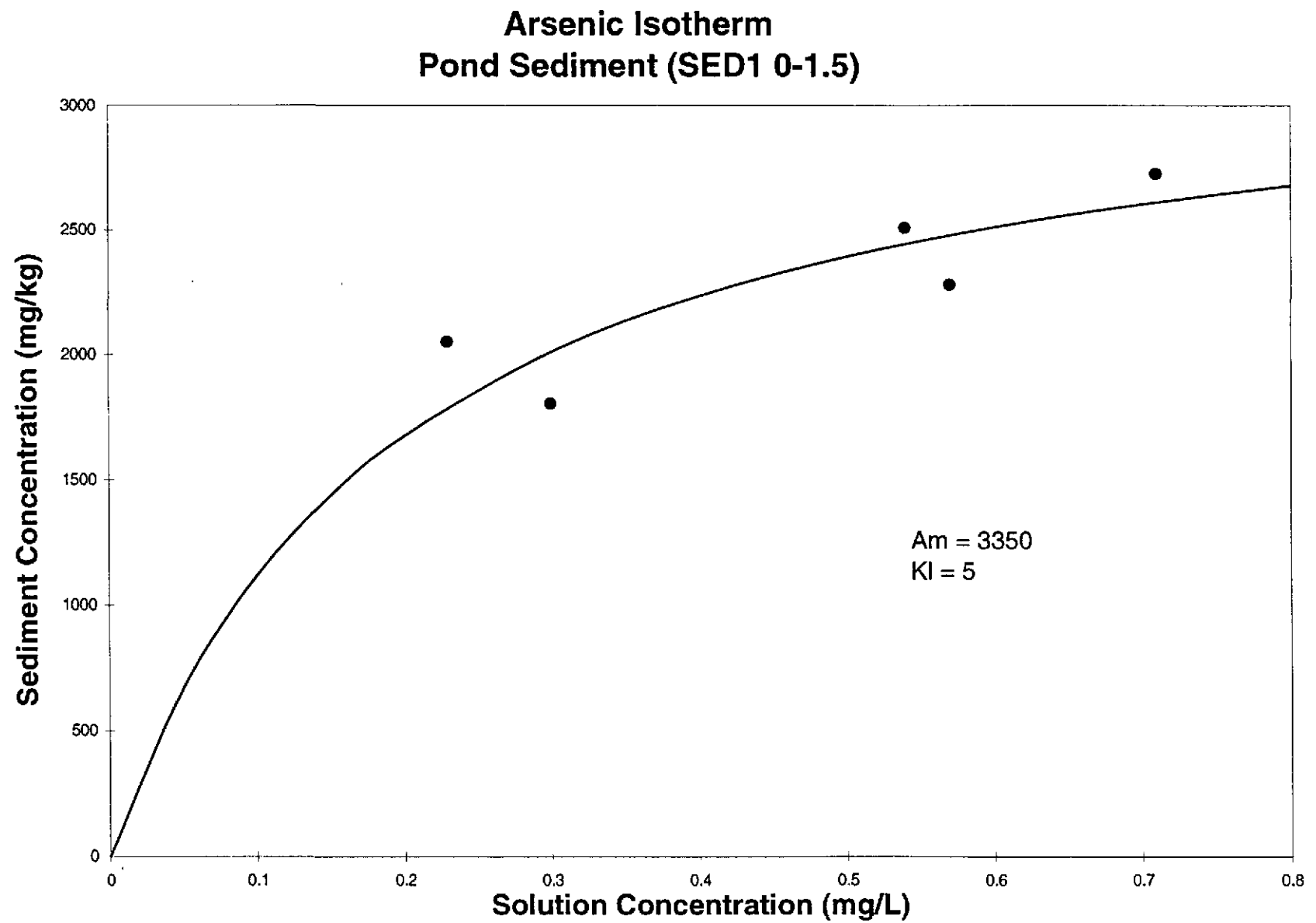


Figure 32 HBHA Pond sediment arsenic adsorption isotherm.

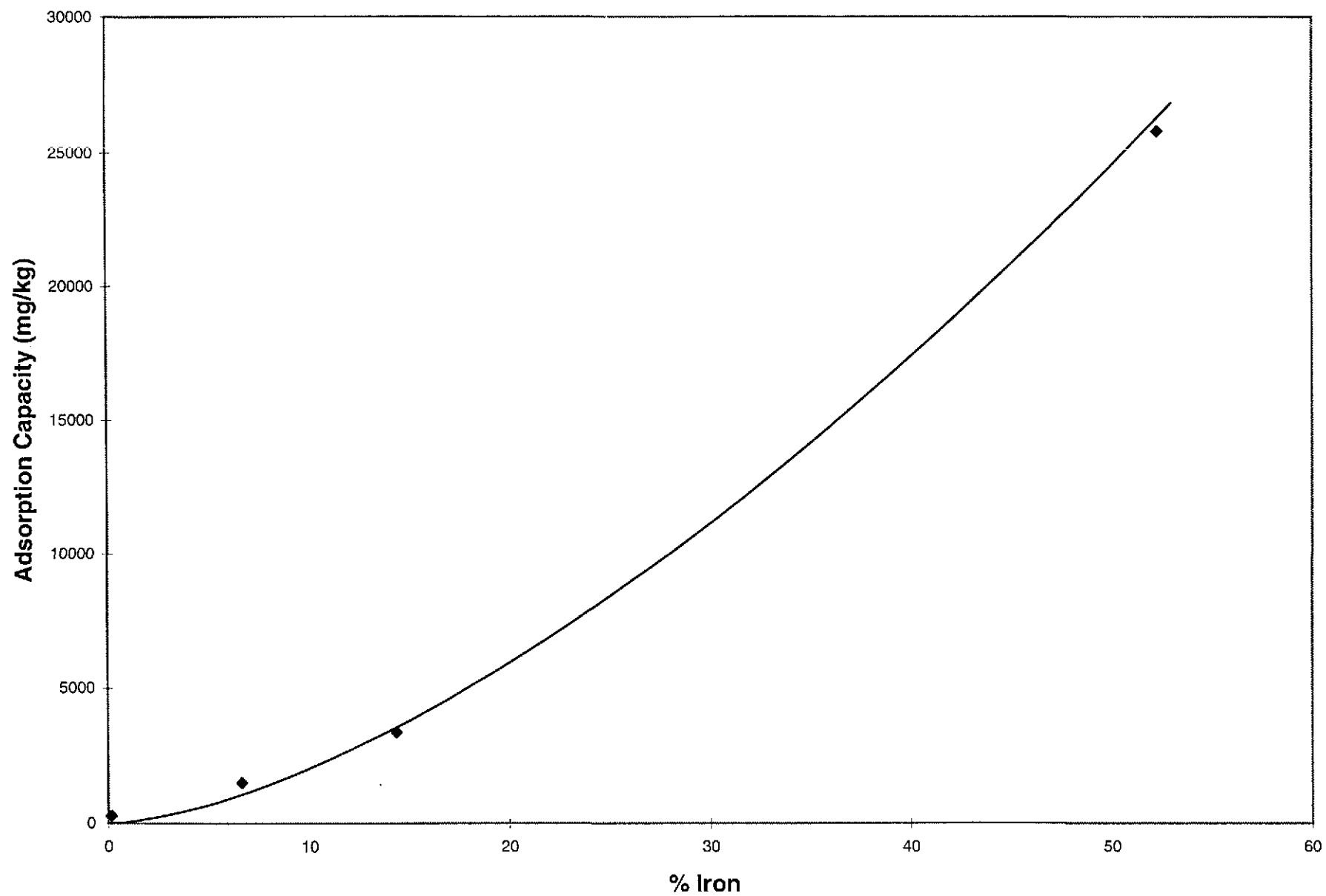


Figure 33 Relationship between Iron Percentage and Arsenic Adsorption Capacity.

### Chromium Isotherm Pond Sediment (SED1 0-1.5)

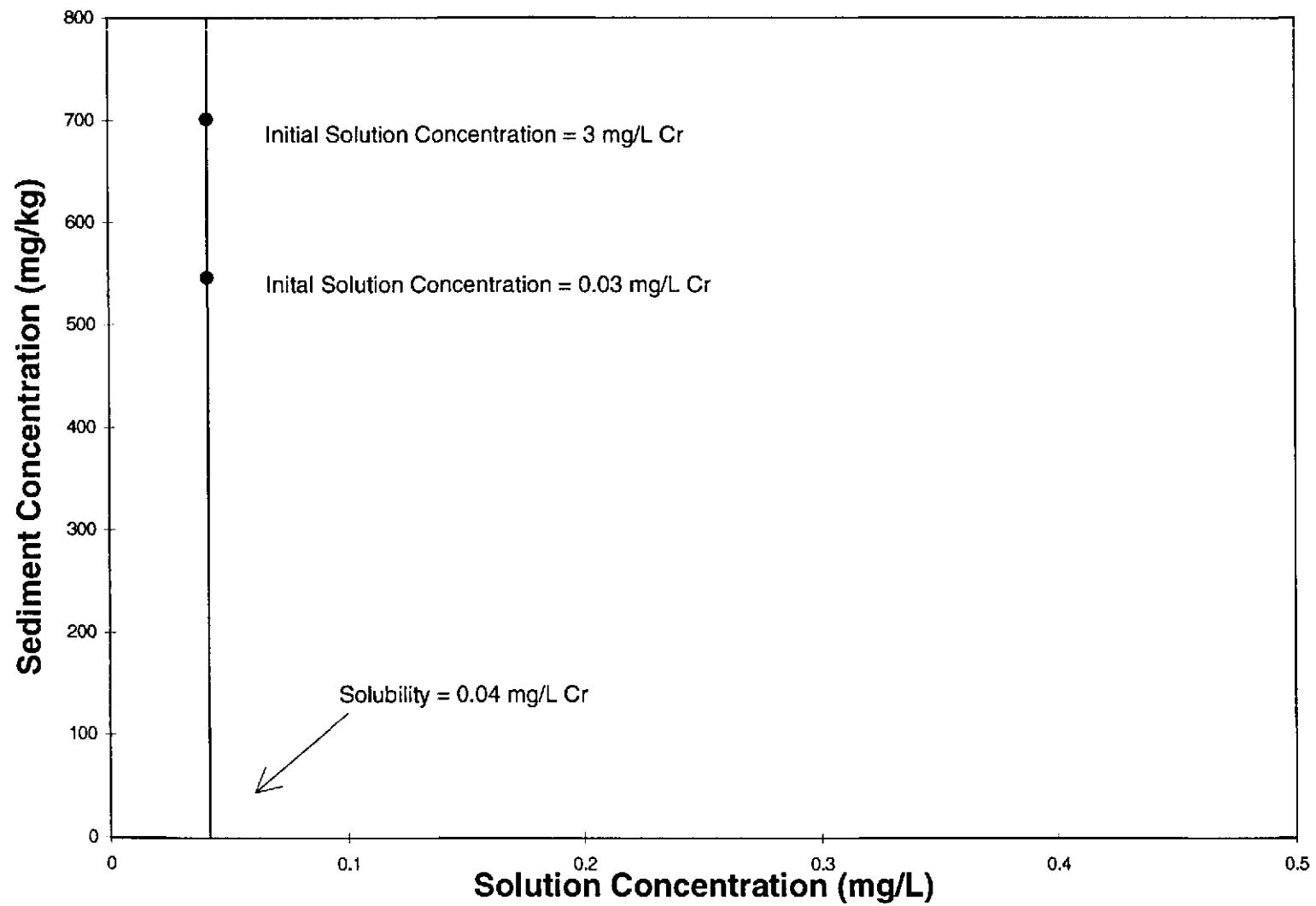


Figure 34 HBHA Pond sediment chromium adsorption isotherm

# Benzene Isotherm Pond Sediment (SED1 0-1.5)

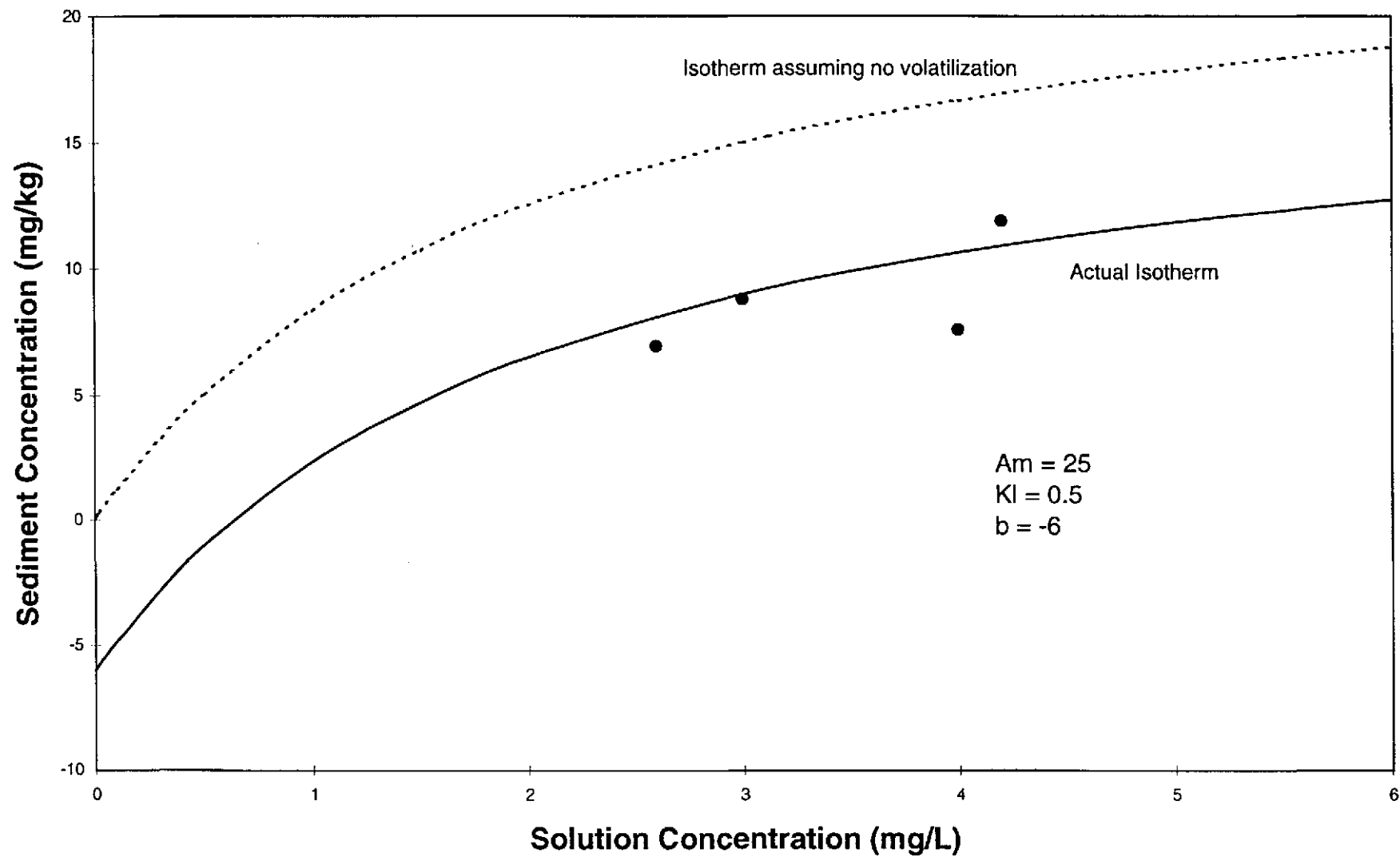


Figure 35 HBHA Pond sediment benzene adsorption isotherm.

**Toluene Isotherm  
Pond Sediment (SED1 0-1.5)**

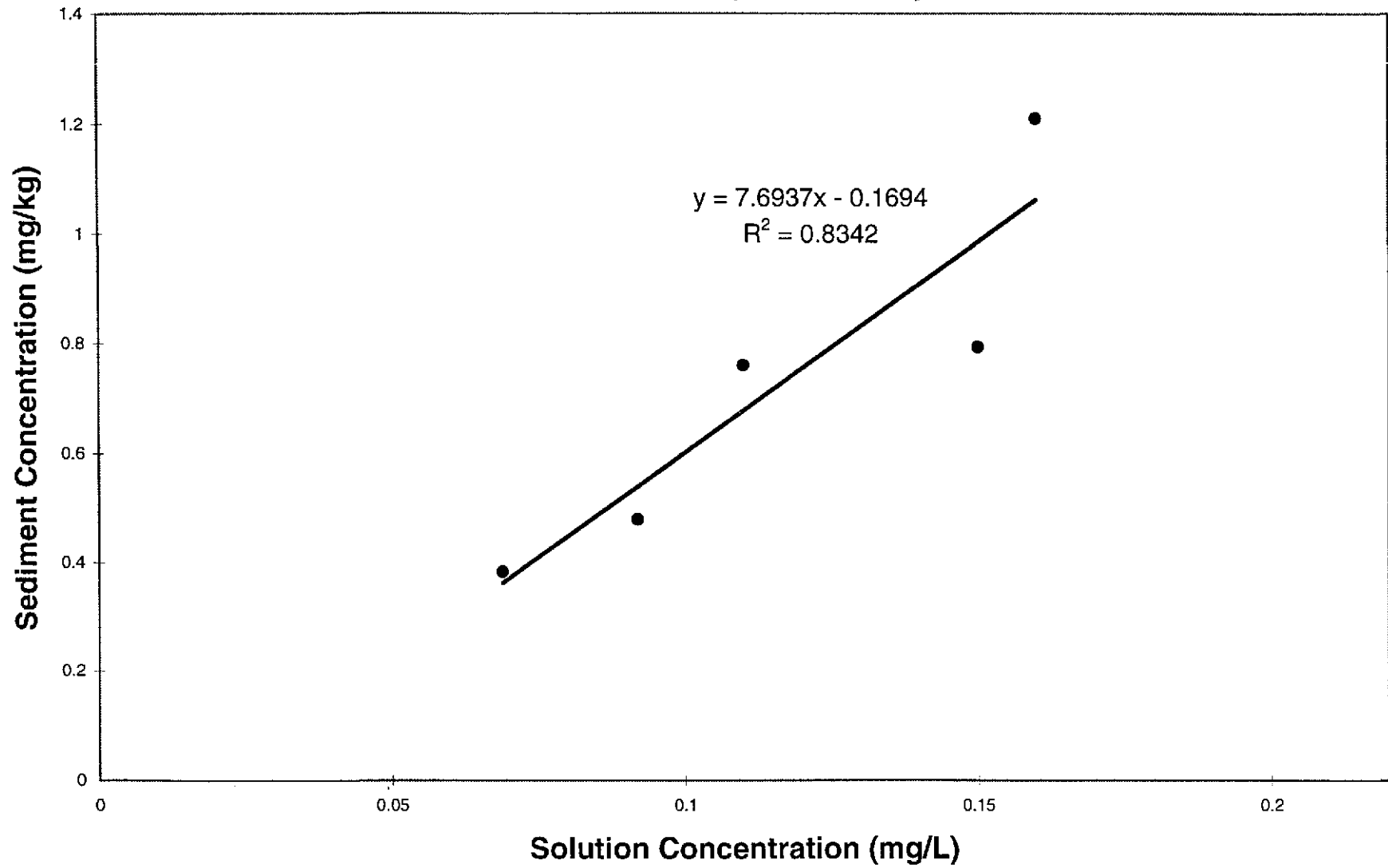


Figure 36 HBHA Pond sediment toluene adsorption isotherm.

# BENZENE

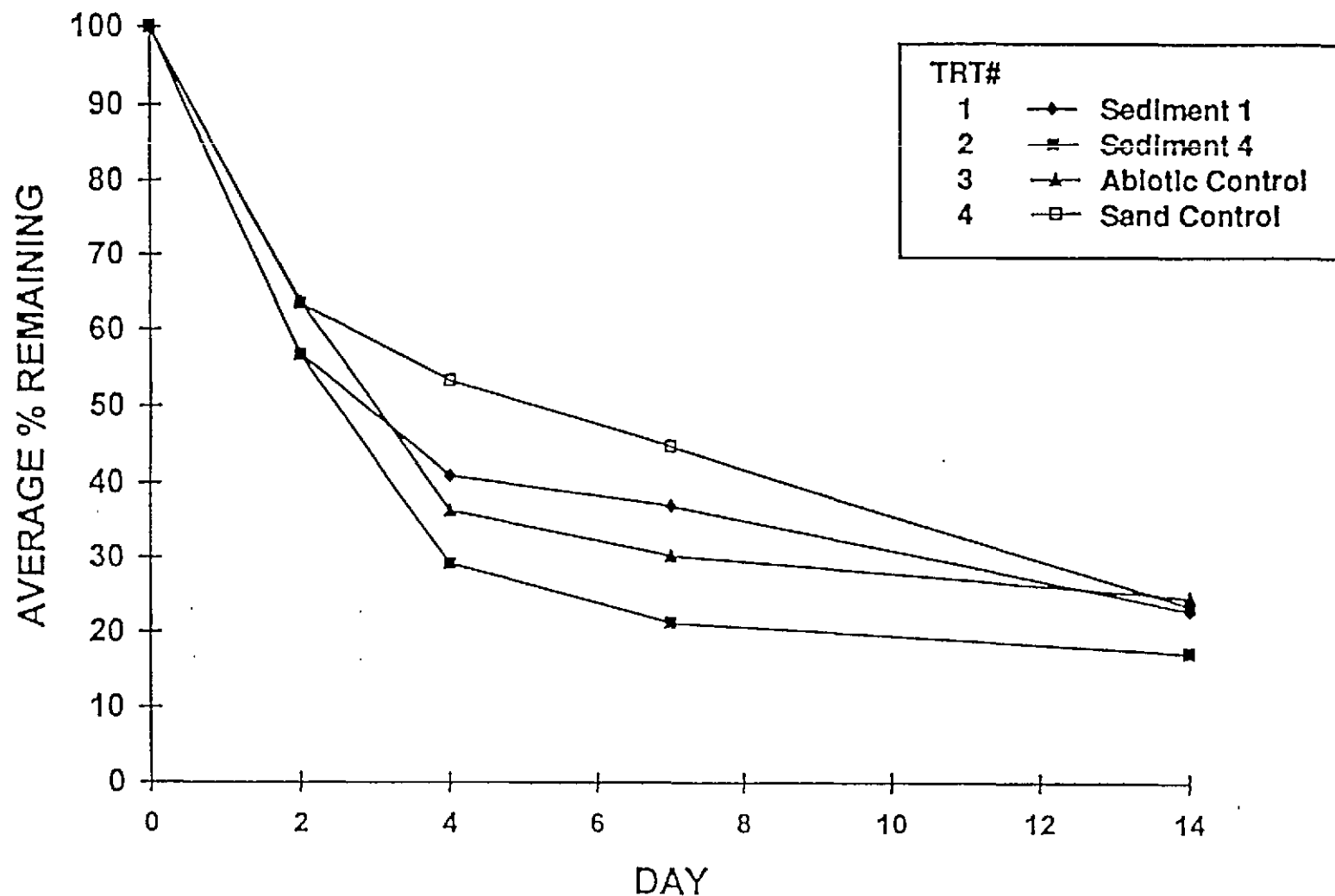


Figure 37  
LOSS OF BENZENE DUE TO BIOTIC AND ABIOTIC  
MECHANISMS UNDER AEROBIC CONDITIONS

SOURCE: ESE

ENVIRONMENTAL SCIENCE  
& ENGINEERING, INC.

We're changing our name to



# TOLUENE

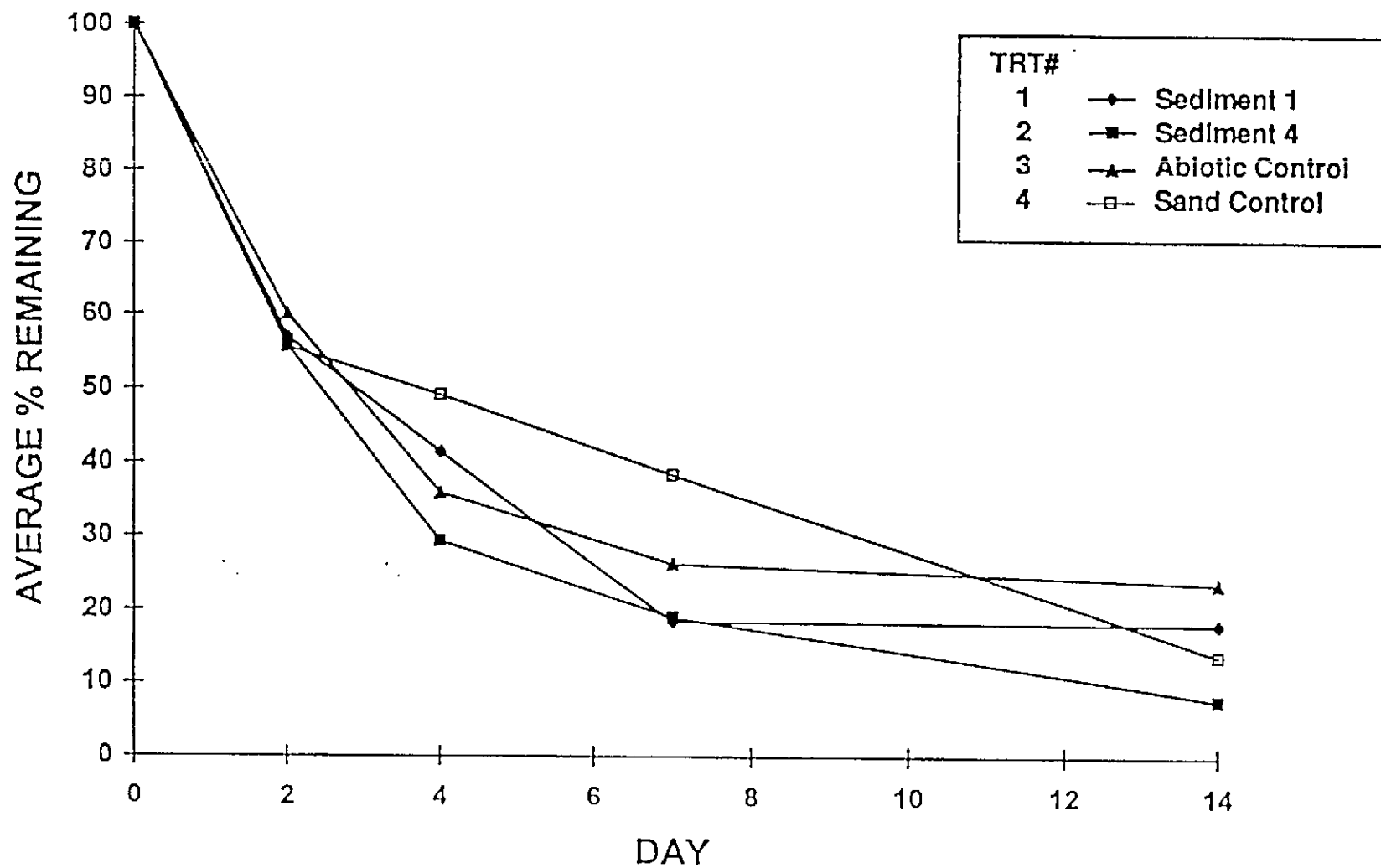


Figure 38  
LOSS OF TOLUENE DUE TO BIOTIC AND ABIOTIC  
MECHANISMS UNDER AEROBIC CONDITIONS

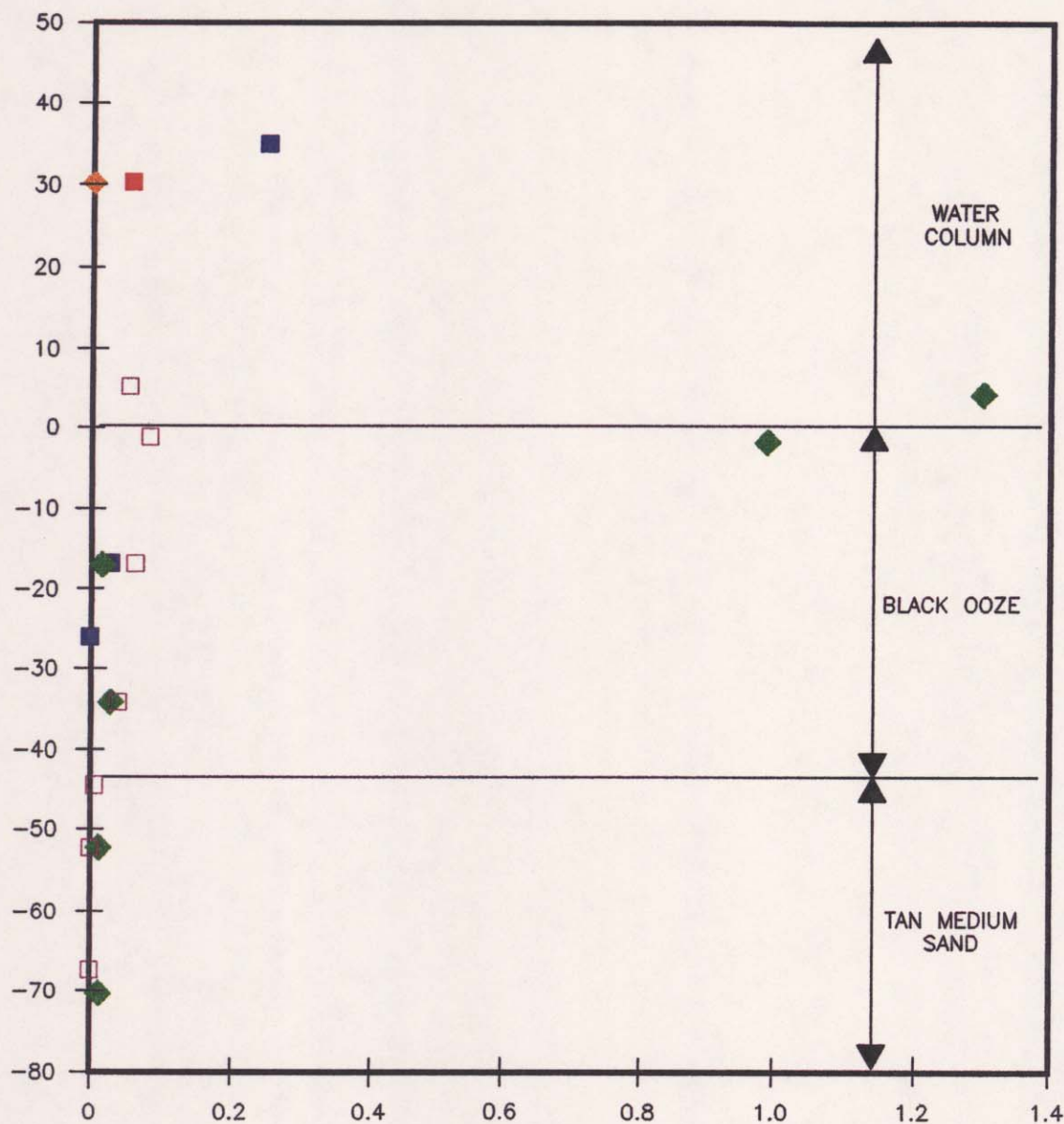
SOURCE: CSE

ENVIRONMENTAL SCIENCE  
& ENGINEERING, INC.

We're changing our name to

**QST**  
BY THE EXPERIMENTAL

DEPTH  
cm



### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## BENZENE IN PORE WATERS (mg/L)

### SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

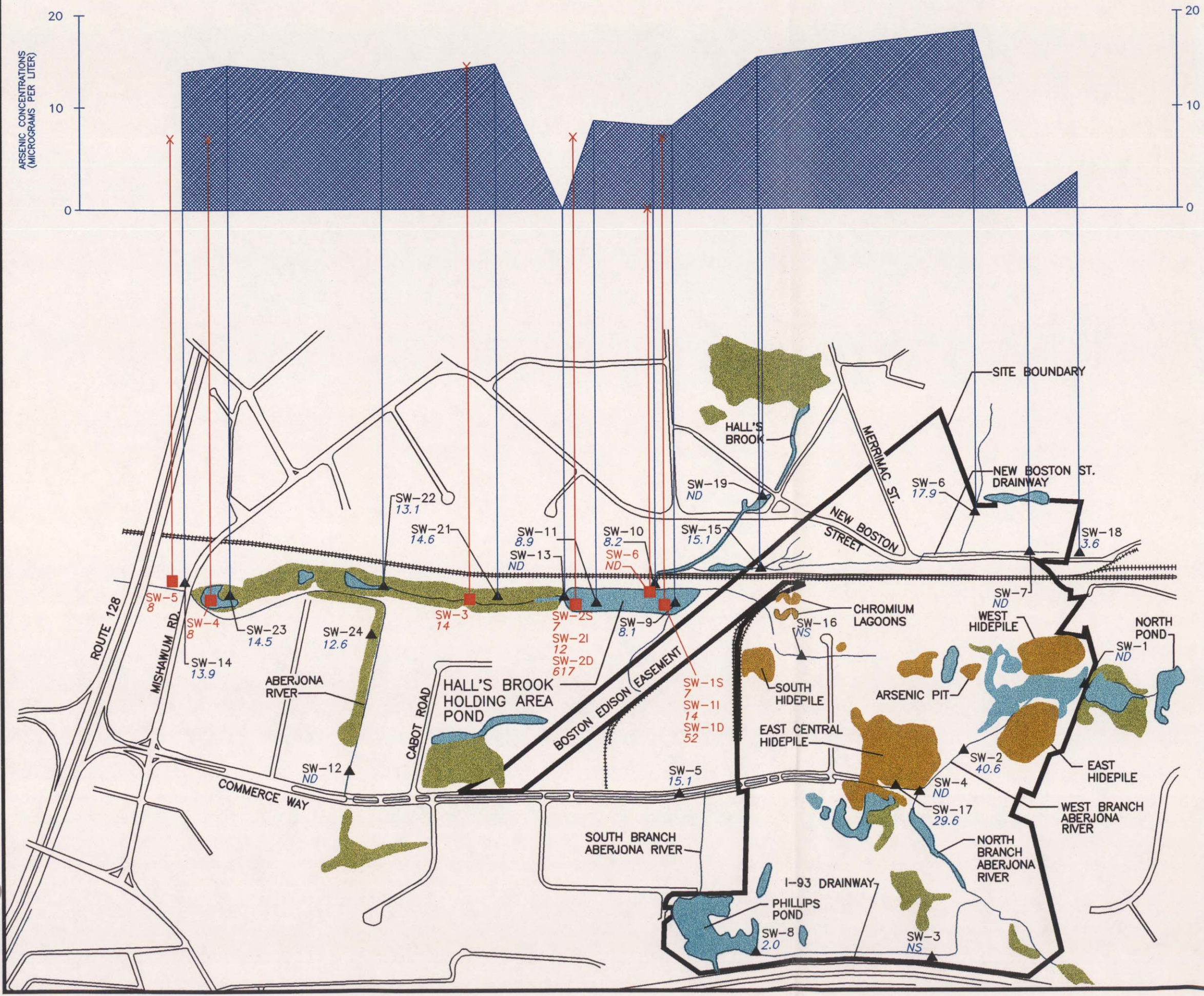
INDUSTRI-PLEX SITE REMEDIAL TRUST

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Environmental Consulting  
& Management

Compiled by: S.W.	Date: 9/97
Prepared by: G.M.	Scale: As Shown
Project Mgr: L.M.	Status: FINAL
File No: M2610604	Project: 06626M10

FIGURE

39



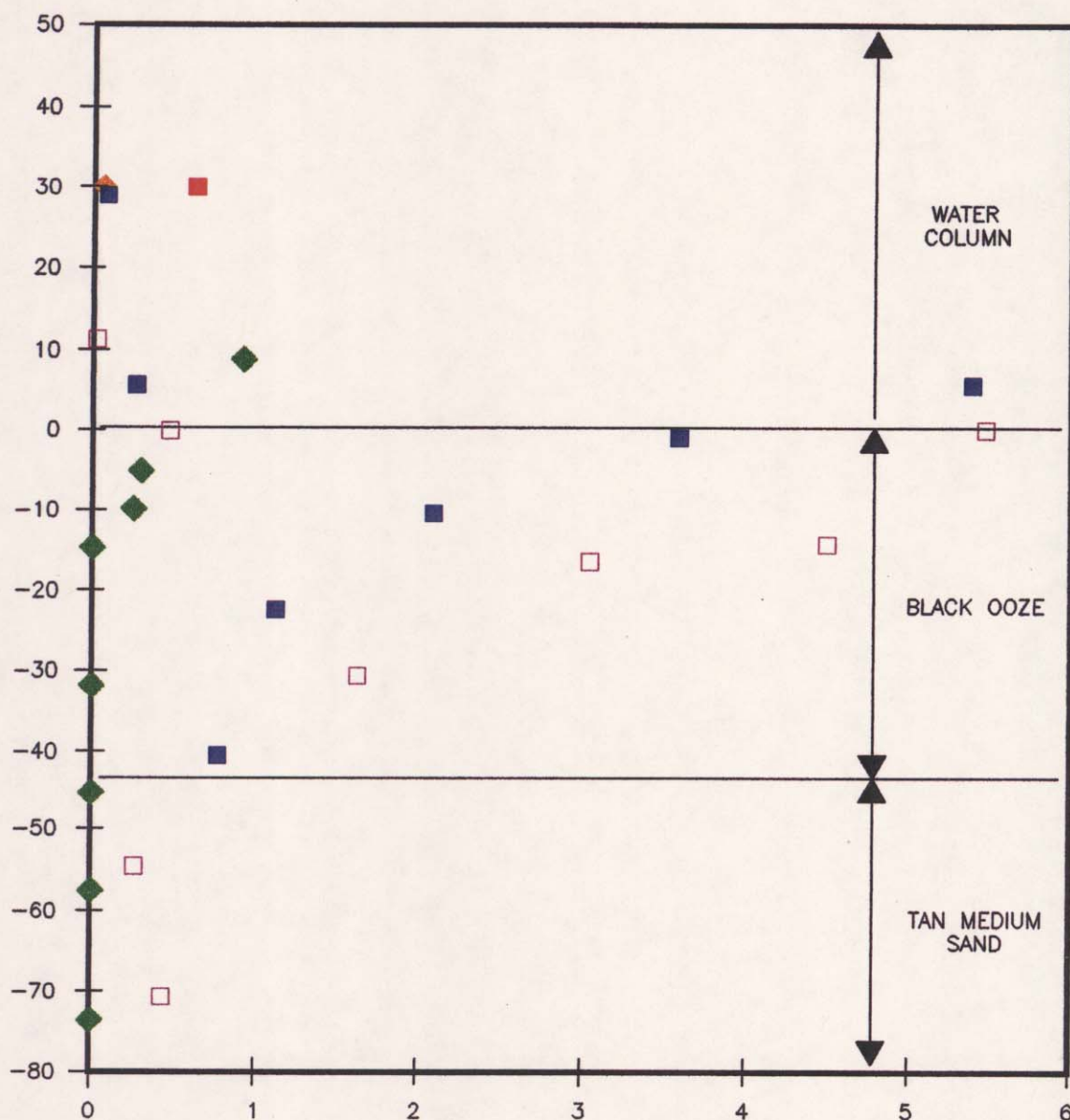
**CONCENTRATIONS OF ARSENIC IN SURFACE WATER**

SUPPLEMENTAL SITE INVESTIGATION

Prepared For: INDUSTRI-PLEX SITE REMEDIAL TRUST

<b>ROUX</b> ROUX ASSOCIATES INC Environmental Consulting & Management	Compiled by: S.W.	Date: 9/97	FIGURE 40
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610615	Project: 06626M10	

DEPTH  
cm



### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## ARSENIC IN PORE WATERS (mg/L)

### SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

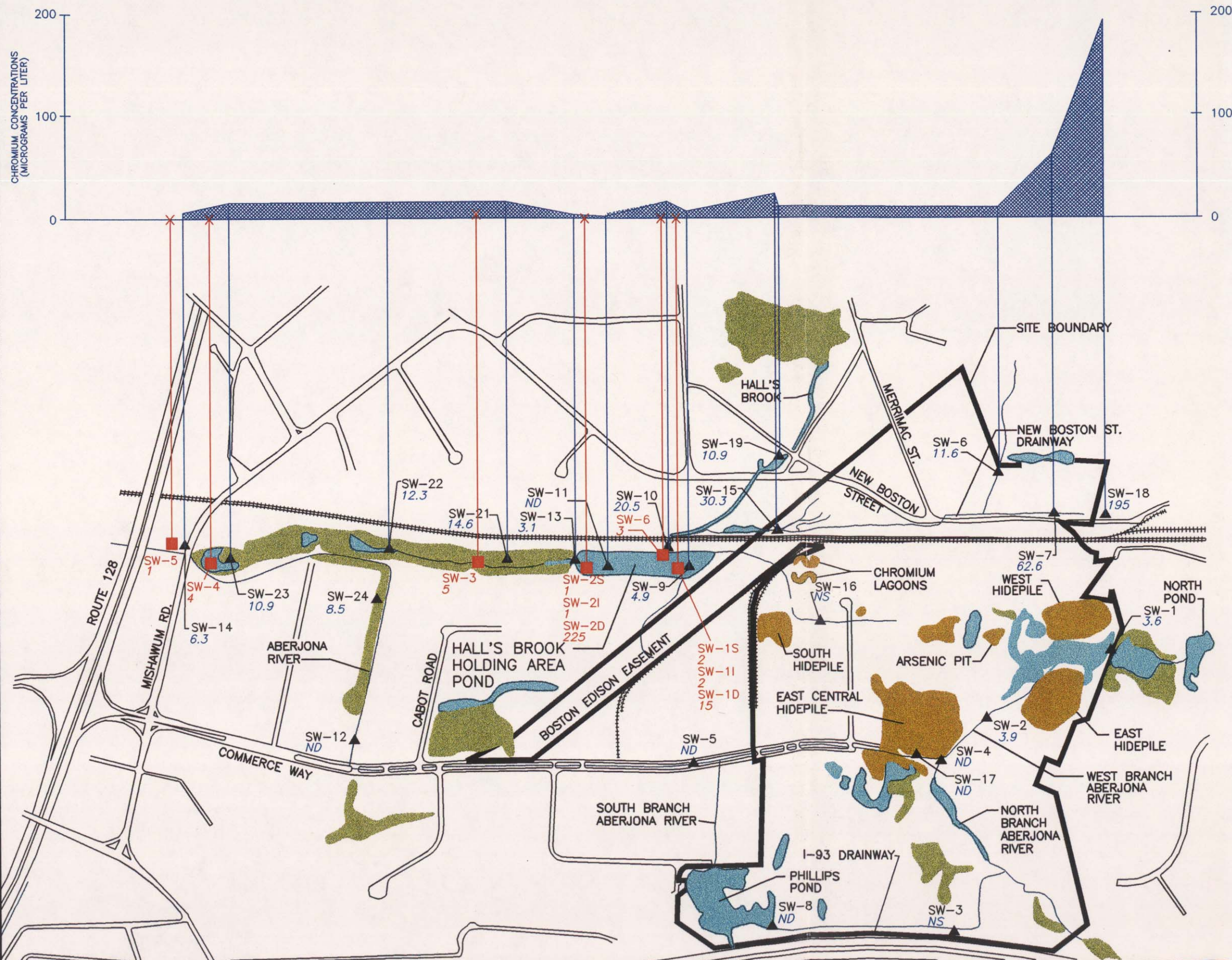
INDUSTRI-PLEX SITE REMEDIAL TRUST

**ROUX**  
ROUX ASSOCIATES INC  
Environmental Consulting  
& Management

Compiled by: S.W.	Date: 9/97
Prepared by: G.M.	Scale: As Shown
Project Mgr: L.M.	Status: FINAL
File No: M2610605	Project: 06626M10

FIGURE

41

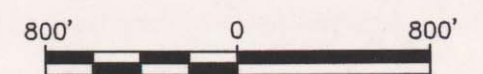


# EXPLANATION

- SW-18▲ 195 GSIP SURFACE-WATER SAMPLE LOCATION AND DESIGNATION
- CONCENTRATION OF CHROMIUM DETECTED IN SURFACE WATER, MEASURED IN MICROGRAMS PER LITER
- SW-3■ 5 SSI SURFACE-WATER SAMPLE LOCATION AND DESIGNATION
- CONCENTRATION OF TOTAL CHROMIUM DETECTED IN SURFACE WATER, MEASURED IN MICROGRAMS PER LITER
- ND - NOT DETECTED
- NS - NOT SAMPLED
- POTENTIAL SOURCE AREA
- WETLANDS
- SURFACE WATER BODIES

NOTE: 1. CHROMIUM CONCENTRATIONS IN THE ABERJONA RIVER UPSTREAM OF MISHAWUM ROAD ARE CONSISTENTLY LOW, AND ARE THEREFORE NOT INCLUDED IN GRAPH.

2. Xs INDICATE CONCENTRATION OF CHROMIUM IN SURFACE WATER DURING SSI



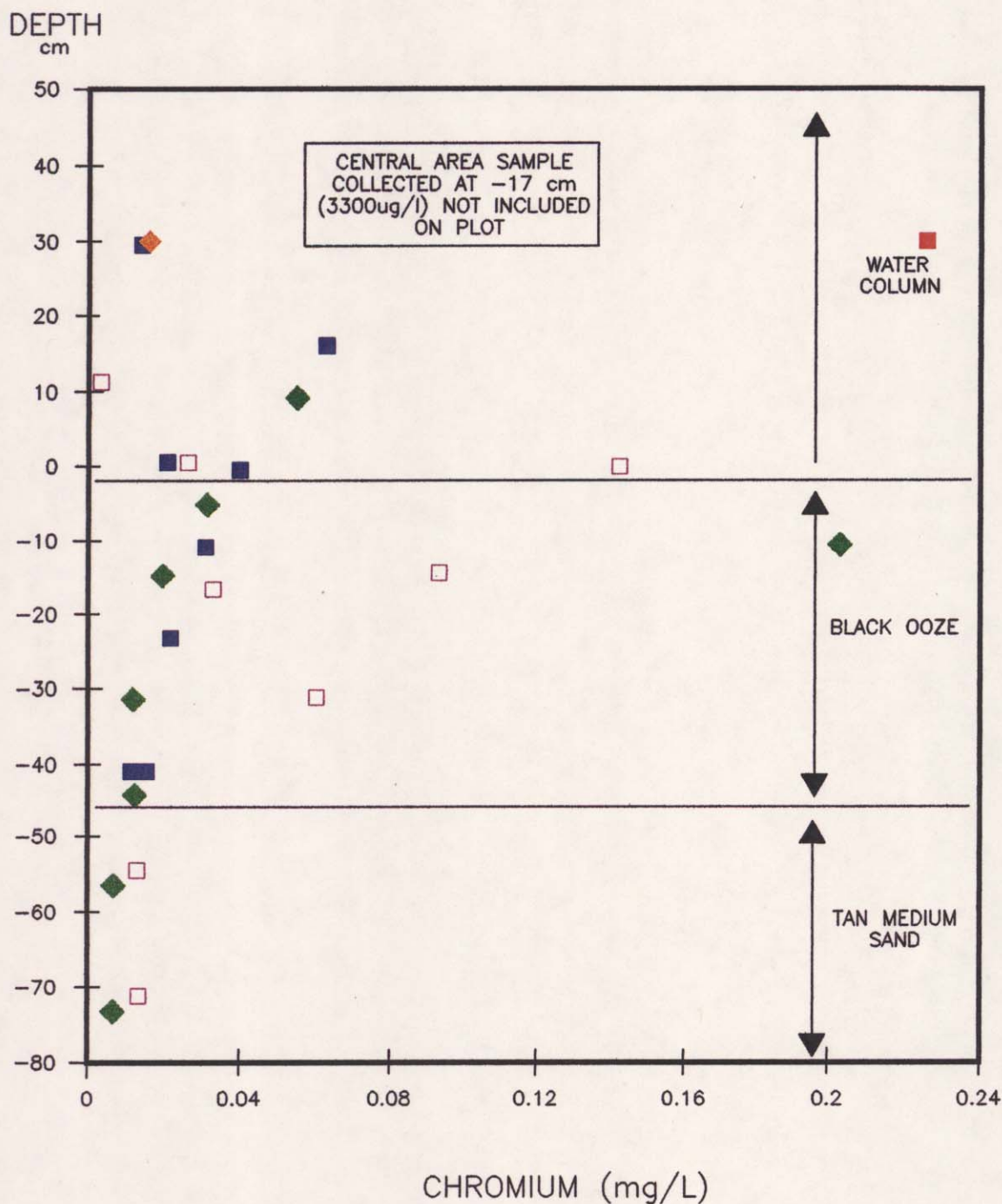
Title:

## CONCENTRATIONS OF CHROMIUM IN SURFACE WATER

SUPPLEMENTAL SITE INVESTIGATION

Prepared For: INDUSTRI-PLEX SITE REMEDIAL TRUST

<b>ROUX</b> ROUX ASSOCIATES INC. Environmental Consulting & Management	Compiled by: S.W.	Date: 9/97	FIGURE 42
	Prepared by: G.M.	Scale: AS SHOWN	
	Project Mgr: L.M.	Status: FINAL	
	File No: M2610616	Project: 06626M10	



### EXPLANATION

- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE CENTRAL PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING THE GSIP INVESTIGATION
- CONSTITUENT CONCENTRATION MEASURED IN THE SOUTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI
- ◆ CONSTITUENT CONCENTRATION MEASURED IN THE NORTHERN PORTION OF THE HALL'S BROOK HOLDING AREA POND DURING SSI

Title:

## TOTAL CHROMIUM IN PORE WATERS (mg/L)

### SUPPLEMENTAL SITE INVESTIGATION

Prepared For:

INDUSTRI-PLEX SITE REMEDIAL TRUST

**ROUX**  
ROUX ASSOCIATES INC  
Environmental Consulting  
& Management

Compiled by: S.W.	Date: 9/97
Prepared by: G.M.	Scale: As Shown
Project Mgr: L.M.	Status: FINAL
File No: M2610606	Project: 06626M10

FIGURE

43

### Dye Concentration vs. Time

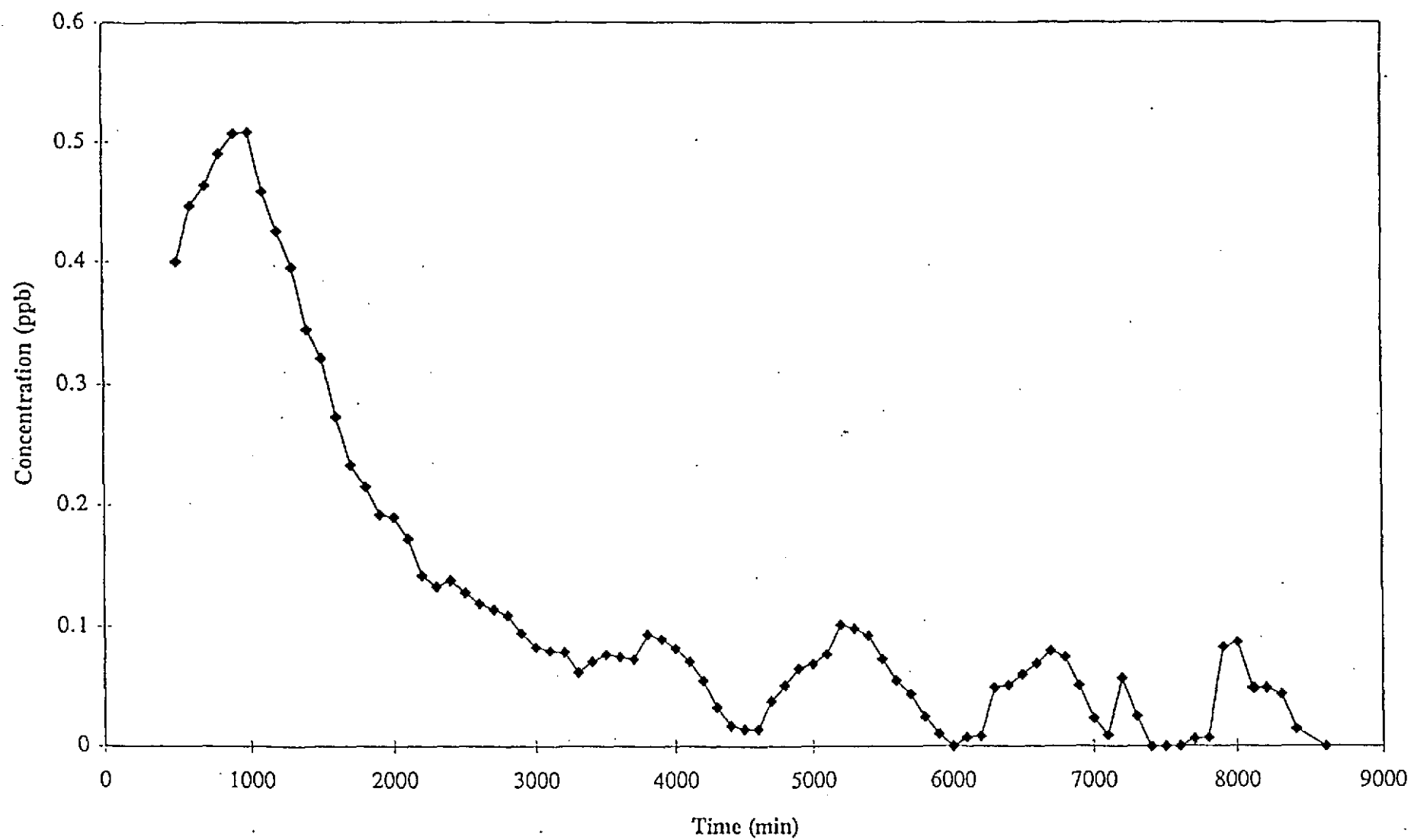


Figure 44  
Dye concentrations detected before 500 minutes are likely erroneous, and are not shown.

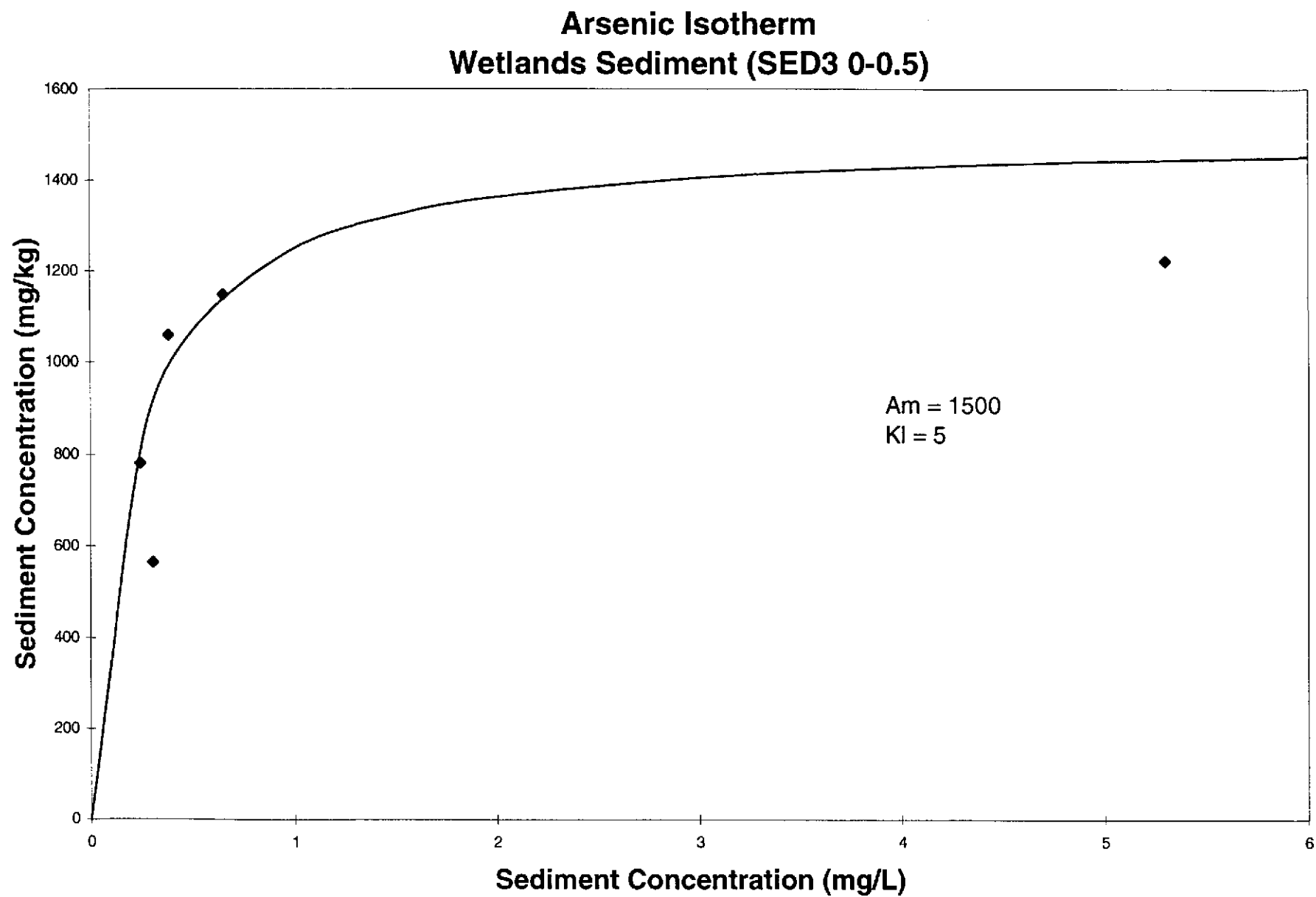


Figure 45 HBHA Wetland sediment arsenic adsorption isotherm.

# Chromium Isotherm Wetlands Sediment (SED3 0-0.5)

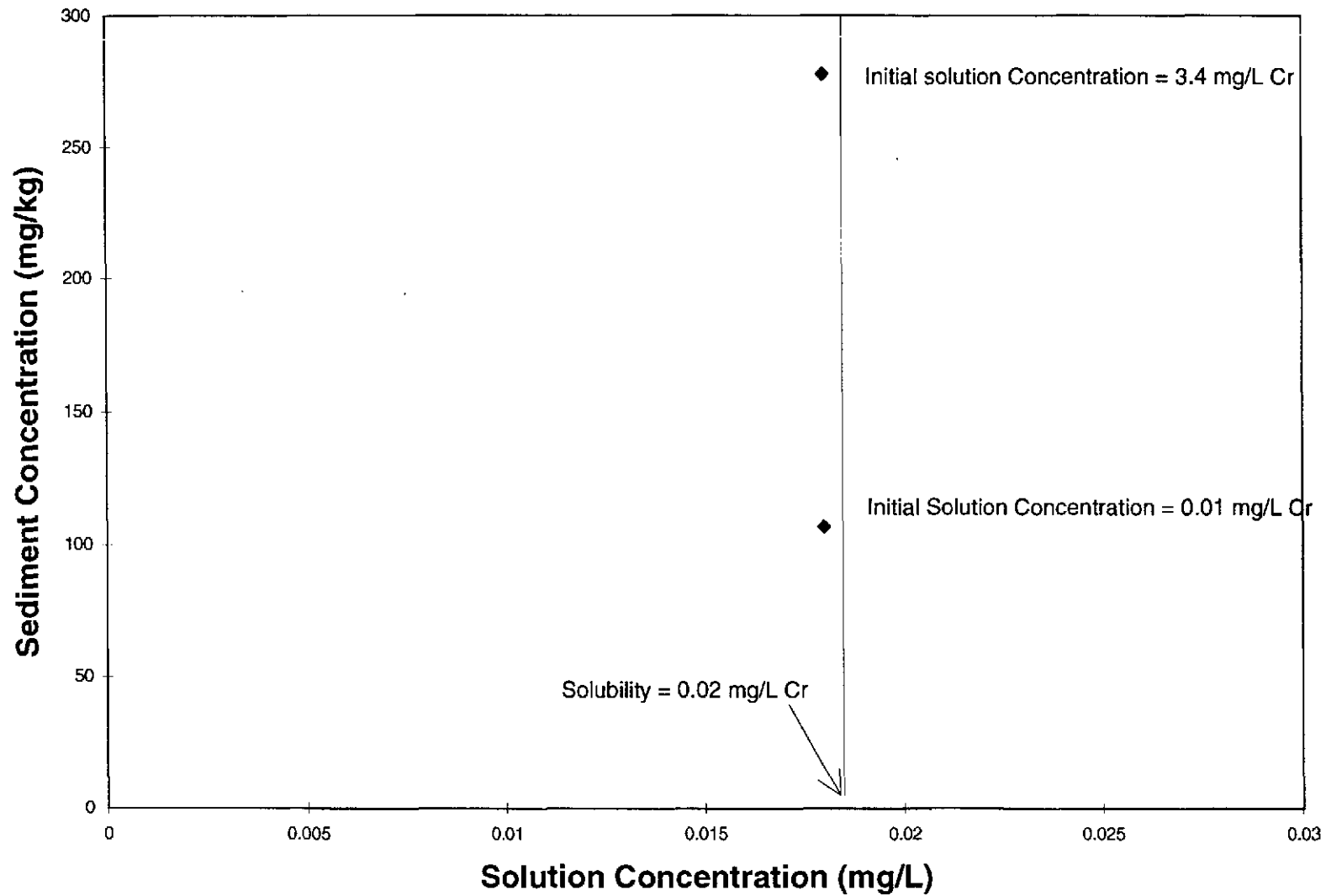


Figure 46 HBHA Wetland sediment chromium adsorption isotherm.

**Benzene Isotherm**  
**Wetlands Sediment (SED3 0-0.5)**

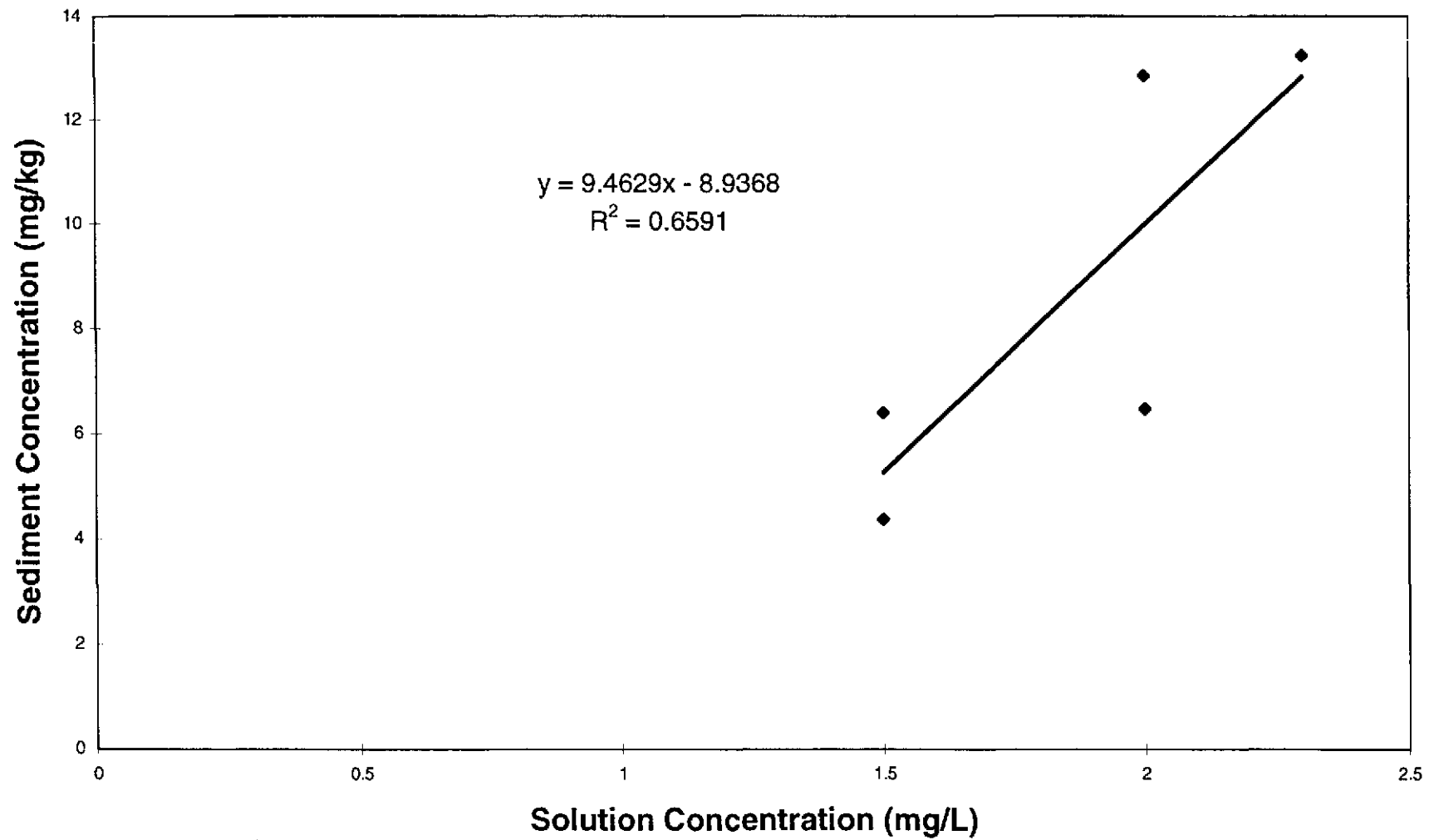


Figure 47 HBHA Wetland sediment benzene adsorption isotherm.





## APPENDIX A

## **APPENDIX A**

### **Ground-Water Quality Analytical Data Reports**



**IEA**  
An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

February 06, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
1377 Motor Parkway  
Islandia, NY 11788

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 8 samples received at our laboratory on December 19-20, 1996. This report contains sections addressing the following information at a minimum:

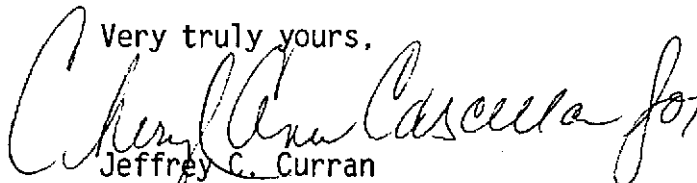
- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

IEA Report #	7096-2874A
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,  
  
Jeffrey C. Curran  
Laboratory Manager

JCC

Schaumburg,  
Illinois  
847-705-0740

N. Billerica,  
Massachusetts  
508-667-1400

Whippany,  
New Jersey  
201-428-8181

Cary,  
North Carolina  
919-677-0090



printed on recycled paper

7096-2874A  
ROUX ASSOCIATES

Case Narrative

Hexavalent Chromium/Nitrate-Nitrogen/Nitrite-Nitrogen - Subcontracted to IEA/MA.

Classical Chemistry - Listed below are the wet chemistry analyte methods and references for the samples analyzed in this SDG. No analytical problems were encountered and all holding times were met.

Analyte	Method	Reference
Alkalinity	310.1	1
Ammonia	350.1	1
Bicarbonate	2320B	2
Carbonate	2320B	2
Chloride	325.2	1
Fluoride	340.2	1
pH	150.1	1
DOC	9060	3
Ferrous Iron	3500-Fe D	2
Trivalent Chromium	7196	3
Sulfide	376.1	1
Sulfate	375.4	1
TOCD	9060	3

References:

1. Methods of Chemical Analysis of Water and Wastes, EPA 600, 1983.
2. Standard Methods for the Examination of Water and Wastewater. 18th edition, 1992.
3. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.

Metals - ICAP metals were determined using a JA61 trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3010/6010.

No problems occurred. All appropriate protocols were employed. All data appears to be consistent.

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5972A GC/MS/DS.

Sample GW-4 was analyzed at a 1:10 dilution due to a high target compound concentration.

TABLE VO-1.0  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	GW-1	GW-4	Quant. Limits with no Dilution
Lab Sample I.D.	VLKLD9	962874A-01	962874A-02	
Method Blank I.D.	VLKLD9	VLKLD9	VLKLD9	
Quant. Factor	1.00	1.00	10.0	
Benzene	U	U	1000	10
Toluene	U	U	150	10
Date Received		12/19/96	12/19/96	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	12/28/96	12/28/96	12/28/96	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.1  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	FB-12/18	TB 121896	GW-3 MS	Quant. Limits with no Dilution
Lab Sample I.D.	962874A-03	962874A-04	962874A-05MS	
Method Blank I.D.	VLKD9	VLKD9	VLKD9	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	56X	10
Toluene	U	U	58X	10
Date Received	12/19/96	12/19/96	12/20/96	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	12/28/96	12/28/96	12/28/96	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
 Quant. Factor = a numerical value which takes into account any  
 variation in sample weight/volume, % moisture and  
 sample dilution.

TABLE VO-1.2  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	GW-3			
Lab Sample I.D.	MSD			
Method Blank I.D.	962874A-05			
Quant. Factor	MSD			Quant.
	VBLKD9			Limits
	1.00			with no
				Dilution
Benzene	53X			10
Toluene	58X			10
Date Received	12/20/96			
Date Extracted	N/A			
Date Analyzed	12/28/96			

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
 Quant. Factor = a numerical value which takes into account any  
 variation in sample weight/volume, % moisture and  
 sample dilution.

TABLE VO-1.3  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	GW-3	GW-3/D	Quant. Limits with no Dilution
Lab Sample I.D.	VLKDA	962874A-05	962874A-06	
Method Blank I.D.	VLKDA	VLKDA	VLKDA	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	U	4J	6J	10
Date Received		12/20/96	12/20/96	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	12/29/96	12/29/96	12/29/96	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.4  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	FB-12/19	TB 121996		
Lab Sample I.D.	962874A-07	962874A-08		Quant. Limits
Method Blank I.D.	VBKDA	VBKDA		with no
Quant. Factor	1.00	1.00		Dilution
Benzene	U	U		10
Toluene	U	U		10
Date Received	12/20/96	12/20/96		
Date Extracted	N/A	N/A		
Date Analyzed	12/29/96	12/29/96		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
 Quant. Factor = a numerical value which takes into account any  
 variation in sample weight/volume, % moisture and  
 sample dilution.

TABLE AS-1.0  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-1	GW-4	FB-12/18	GW-3
Lab Sample I.D.	962874A-01	962874A-02	962874A-03	962874A-05
Arsenic	5.0U	718.	5.0U	451.
Calcium	161000	32700	91.6B	20000
Chromium	1.0U	132.	1.0U	35.9
Copper	1.6B	2.3B	1.0U	1.0U
Iron	4210	1800	34.0U	1140
Magnesium	38300	63800	20.0U	97900
Potassium	9210	43600	267.U	4710B
Sodium	40300	115000	207.B	8580
Zinc	31.1	33.7	11.5B	17.8B

See Appendix for qualifier definitions

TABLE AS-1.1  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-3 D	GW-3 S	GW-3/D	FB-12/19
Lab Sample I.D.	962874A-05D	962874A-05S	962874A-06	962874A-07
Arsenic	448.	500.	442.	5.0U
Calcium	20200	NR	20000	14900
Chromium	36.3	215.	36.6	2.0B
Copper	1.0U	239.	1.0U	6.9B
Iron	1140	2030	1110	34.0U
Magnesium	99300	NR	99600	1260B
Potassium	4840B	NR	4890B	2140B
Sodium	8780	NR	8810	7790
Zinc	17.5B	501.	16.5B	12.4B

See Appendix for qualifier definitions

TABLE AS-1.2  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-1	GW-4	GW-3	GW-3 D
Lab Sample I.D.	962874A-01	962874A-02	962874A-05	962874A-05D
Arsenic	NR	NR	NR	NR
Calcium	NR	NR	NR	NR
Chromium	NR	NR	NR	NR
Copper	628.	1010	279.	295.
Iron	169000	205000	287000	293000
Magnesium	NR	NR	NR	NR
Potassium	NR	NR	NR	NR
Sodium	NR	NR	NR	NR
Zinc	607.	636.	837.	857.

See Appendix for qualifier definitions

TABLE AS-1.3  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-3 S	GW-3/D		
Lab Sample I.D.	962874A-05S	962874A-06		
Arsenic	NR	NR		
Calcium	NR	NR		
Chromium	NR	NR		
Copper	534.	4.2B		
Iron	292000	13900		
Magnesium	NR	NR		
Potassium	NR	NR		
Sodium	NR	NR		
Zinc	1320	27.5		

See Appendix for qualifier definitions

TABLE CC-1.0(R)  
7096-2874A  
ROUX ASSOCIATES  
MISCELLANEOUS

All values are mg/L unless noted.

<u>Parameter</u>	<u>GW-1</u>	<u>GW-4</u>	<u>FB-12/18</u>	<u>GW-3</u>	<u>GW-3/D</u>	<u>FB-12/19</u>
Alkalinity, as CaCO <sub>3</sub>	237	6,420	NR	2,030	2,020	NR
Ammonia-Nitrogen	1.61	1,270	NR	422	388	NR
Bicarbonate	237	6,420	NR	2,030	2,020	NR
Carbonate, as CaCO <sub>3</sub>	<2.00	39.9	NR	5.80	5.50	NR
Chloride	14.5	95.9	NR	21.2	21.2	NR
Fluoride	<0.100	0.510	NR	0.170	0.170	NR
DOC	7.28	<1.0	NR	46.4	34.8	NR
Trivalent Chromium	0.010	0.132	NR	0.036	0.037	NR
Ferrous Iron	2.11	1.34	<0.50	3.71	1.75	<0.50
pH, S.U.	7.03	8.30	NR	7.95	7.94	NR
Sulfate	527	<10.0	NR	19.3	<10.0	NR
Sulfide	<1.0	<1.0	NR	<1.0	<1.0	NR
Total Organic Carbon	7.40	<1.0	NR	47.1	34.5	NR

NR - Not Requested



IEA ID: 0070-395  
Received: 12/19/96

01/09/97, 15



# IEA

An Aquarion Company

## IEA Laboratory Results

Client: IEA - CT.  
Project: 7096-2874A  
Report Date: 01/06/97

IEA ID: 0070-397  
Received: 12/19/96

IEA #	Client ID	Parameter	Results	Units	PQL	Date Analyzed	Analyst	Method
01	GW-3	Hexavalent Chromium	BQL	mg/L	0.050	12/20/96	CCV/ND	307B/7196
01	GW-3	Nitrate-N	BQL	mg/L	0.20	01/03/97	CCV	353.2
01	GW-3	Nitrite-N	BQL	mg/L	0.020	12/20/96	CCV/ND/GMP	354.1
02	GW-3/D	Hexavalent Chromium	BQL	mg/L	0.050	12/20/96	CCV/ND	307B/7196
02	GW-3/D	Nitrate-N	BQL	mg/L	0.20	01/03/97	CCV	353.2
02	GW-3/D	Nitrite-N	BQL	mg/L	0.020	12/20/96	CCV/ND/GMP	354.1

### Comments:

PQL == Practical quantitation limit.

BQL == Below quantitation limit.



## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).
- BQL - Below quantitation limit.

## INORGANICS APPENDIX

### C - Concentration qualifiers

- U - Indicates analyte was not detected at method reporting limit.
- B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

- E - Reported value is estimated because of the presence of interference
- M - Duplicate injection precision not met
- N - Spiked sample recovery not within control limits
- S - The reported value was determined by the method of standard additions (MSA)
- W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance
- \* - Duplicate analysis not within control limit
- + - Correlation coefficient for MSA is less than 0.995

### M - Method codes

- P - ICP
- A - Flame AA
- F - Furnace AA
- CV - Cold vapor AA (manual)
- C - Cyanide
- NR - Not Required
- NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/ Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/ Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non- Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/ Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/ Hazardous Waste	263

7096-2874A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

CLIENT ID	LAB ID	MATRIX	DATE COLLECTED	DATE RECEIVED
GW-1	962874A-01	WATER	12/18/96	12/19/96
GW-4	962874A-02	WATER	12/18/96	12/19/96
FB-12/18	962874A-03	WATER	12/18/96	12/19/96
TB 121896	962874A-04	WATER	12/18/96	12/19/96
GW-3	962874A-05	WATER	12/19/96	12/20/96
GW-3	962874A-05D	WATER	12/19/96	12/20/96
GW-3	962874A-05MS	WATER	12/19/96	12/20/96
GW-3	962874A-05MSD	WATER	12/19/96	12/20/96
GW-3	962874A-05S	WATER	12/19/96	12/20/96
GW-3/D	962874A-06	WATER	12/19/96	12/20/96
FB-12/19	962874A-07	WATER	12/19/96	12/20/96
TB 121996	962874A-08	WATER	12/19/96	12/20/96

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: GW-1, GW-4, FB-12/18, TB 121896, GW-3, GW-3, GW-3, GW-3/D, FB-12/19, TB 121996, GW-3, GW-3  
Job Number: 7096-2874A

Date: 1/20/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
4	WATER	AMMONIA-350.2	Ammonia		
4	WATER	BICARBONATE-406C	Bicarbonate		
4	WATER	CARBONATE-2320B	Carbonate		
	WATER	CC-MISC	Miscellaneous Classi		
	WATER	CHLORIDE-325.2	Chloride		
8	WATER	CR6-SW846	Hexavalent Chromium		
8	WATER	FLUORIDE-340.2	Fluoride		
6	WATER	MET-SW846-MISC	Miscellaneous Metals		
8	WATER	MET-SW846-MISC-D	Miscellaneous Metals		
8	WATER	NITRATE-353.2	Nitrate-Nitrogen		
8	WATER	NITRITE-353.2	Nitrite-Nitrogen		
4	WATER	SULFATE-375.4	Sulfate		
4	WATER	SULFIDE-376.1	Sulfide		
4	WATER	TOC-9060-DUP	Total Organic Carbon		
10	WATER	VOA-CLP3.1-MISC	Miscellaneous Volati		



# IEA

An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

February 20, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
1377 Motor Parkway  
Islandia, NY 11788

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 17 samples received at our laboratory on January 21-23, 1997. This report contains sections addressing the following information at a minimum:

- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

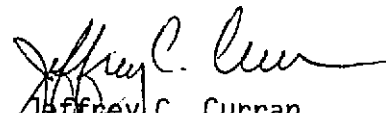
IEA Report #	7097-0133A
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,

  
Jeffrey C. Curran  
Laboratory Manager

JCC

Schaumburg,  
Illinois  
847-705-0740

N. Billerica,  
Massachusetts  
508-667-1400

Whippany,  
New Jersey  
201-428-8181

Cary,  
North Carolina  
919-677-0090



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7097-0133A  
ROUX ASSOCIATES

Case Narrative

**Metals** - ICAP metals were determined using a JA61 simultaneous ICAP and a JA61E trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3010/6010.

Two "E" flags resulted from serial dilution analysis of sample MC-1I for potassium and sodium. There is no apparent reason for these flags.

Sample MC-1D was analyzed at a 1:10 dilution due to the high concentration of analytes present in the sample.

No other problems occurred during analysis. All appropriate protocols were employed. All data appears to be consistent.

IEC's are electronically employed by the TJA ICAP-61 and ICAP JA61E trace. However, the ICSA is utilized as a monitoring device to detect any additional adjustments that may be required. These modifications are calculated and applied manually. They are so noted in the raw data.

**Classical Chemistry** - Listed below are the wet chemistry analyte methods and references for the samples analyzed in this SDG. Misc-cc 1 reported as DOC, misc-cc 2 reported as ferrous iron, and misc-cc 3 reported as trivalent chromium. No analytical problems were encountered and all holding times were met.

Analyte	Method	Reference
Ammonia	350.1	1
Bicarbonate	2320B	2
Carbonate	2320B	2
Chloride	325.2	1
Fluoride	340.2	1
DOC	9060	3
Ferrous Iron	3500-Fe D	2
Nitrate	353.2	1
Nitrite	353.2	1
Trivalent Chromium	7196	3
Sulfide	376.1	1
Sulfate	375.4	1
TOCD	9060	3

References:

1. Methods of Chemical Analysis of Water and Wastes, EPA 600, 1983.
2. Standard Methods for the Examination of Water and Wastewater. 18th edition, 1992.
3. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5972A GC/MS/DS.

Sample MC-1D was analyzed at a 1:100 dilution due to a high target compound concentration.

No problems were encountered.

TABLE VO-1.0  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	GW-2	TB-01/20	Quant. Limits with no Dilution
Lab Sample I.D.	VBLKD4	970133A-01	970133A-03	
Method Blank I.D.	VBLKD4	VBLKD4	VBLKD4	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	U	U	U	10
Date Received		01/21/97	01/21/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/27/97	01/28/97	01/28/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.1  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	MC-2S	MC-2I	MC-2D	Quant. Limits with no Dilution
Lab Sample I.D.	970133A-04	970133A-05	970133A-06	
Method Blank I.D.	VELKD4	VELKD4	VELKD4	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	U	U	U	10
Date Received	01/22/97	01/22/97	01/22/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/28/97	01/28/97	01/28/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.2  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	FB-01/21	TB-01/21	GW-5	
Lab Sample I.D.	970133A-07	970133A-08	970133A-09	Quant. Limits
Method Blank I.D.	VELKD4	VELKD4	VELKD4	with no
Quant. Factor	1.00	1.00	1.00	Dilution
Benzene	U	U	U	10
Toluene	U	U	U	10
Date Received	01/22/97	01/22/97	01/22/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/28/97	01/28/97	01/28/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.3  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	FB-01/20	MC-1S	Quant. Limits with no Dilution
Lab Sample I.D.	VBLKD7	970133A-02	970133A-10	
Method Blank I.D.	VBLKD7	VBLKD7	VBLKD7	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	160	10
Toluene	U	U	U	10
Date Received		01/21/97	01/23/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/29/97	01/29/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.4  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	MC-1I	MC-1I MS	MC-1I MSD	Quant. Limits with no Dilution
Lab Sample I.D.	970133A-11	970133A-11MS	970133A-11 MSD	
Method Blank I.D.	VLK7	VLK7	VLK7	
Quant. Factor	1.00	1.00	1.00	
Benzene	160	200X	200X	10
Toluene	U	46X	46X	10
Date Received	01/23/97	01/23/97	01/23/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/29/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.5  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	MC-1I/R	MC-3S	MC-3I	Quant. Limits with no Dilution
Lab Sample I.D.	970133A-12	970133A-14	970133A-15	
Method Blank I.D.	VBKLD7	VBKLD7	VBKLD7	
Quant. Factor	1.00	1.00	1.00	
Benzene	160	U	U	10
Toluene	U	U	U	10
Date Received	01/23/97	01/23/97	01/23/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.6  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	MC-3D	TB-01/22		
Lab Sample I.D.	970133A-16	970133A-17		Quant. Limits
Method Blank I.D.	VELKD7	VELKD7		with no
Quant. Factor	1.00	1.00		Dilution
Benzene	U	U		10
Toluene	U	U		10
Date Received	01/23/97	01/23/97		
Date Extracted	N/A	N/A		
Date Analyzed	01/30/97	01/29/97		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor

Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.7  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	MC-1D		Quant. Limits with no Dilution
Lab Sample I.D.	VBKLD9	970133A-13		
Method Blank I.D.	VBKLD9	VBKLD9		
Quant. Factor	1.00	100.		
Benzene	U	14000		10
Toluene	U	420J		10
Date Received		01/23/97		
Date Extracted	N/A	N/A		
Date Analyzed	01/30/97	01/30/97		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE AS-1.0  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-2	FB-01/20	MC-2S	MC-2I
Lab Sample I.D.	970133A-01	970133A-02	970133A-04	970133A-05
Arsenic	31.8	6.0U	12.6	8.8B
Calcium	94900	NR	49800	60800
Chromium	16.8	1.0U	1.0U	1.0U
Copper	2610	NR	NR	NR
Iron	24700	NR	12100	35600
Magnesium	9550	NR	7970	15900
Potassium	7210E	NR	7150E	6110E
Sodium	59100E	NR	100000E	122000E
Zinc	664.	NR	NR	NR

See Appendix for qualifier definitions

TABLE AS-1.1  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	MC-2D	FB-01/21	GW-5	MC-1S
Lab Sample I.D.	970133A-06	970133A-07	970133A-09	970133A-10
Arsenic	6.0U	6.0U	51.4	45.5
Calcium	39400	NR	201000	157000
Chromium	1.0U	1.0U	48.9	18.1
Copper	NR	NR	1.0U	NR
Iron	7660	NR	5890	2910
Magnesium	8310	NR	38000	30100
Potassium	3170BE	NR	5400E	4080BE
Sodium	19500E	NR	48700E	29600E
Zinc	NR	NR	11.6B	NR

See Appendix for qualifier definitions

TABLE AS-1.2  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	MC-1I	MC-1I D	MC-1I S	MC-1I/R
Lab Sample I.D.	970133A-11	970133A-11D	970133A-11S	970133A-12
Arsenic	547.	536.	567.	535.
Calcium	76300	75400	NR	NR
Chromium	25.6	25.1	194.	25.2
Copper	NR	NR	NR	NR
Iron	4760	4700	5500	NR
Magnesium	68900	67500	NR	NR
Potassium	20900E	20200	NR	NR
Sodium	108000E	106000	NR	NR
Zinc	NR	NR	NR	NR

See Appendix for qualifier definitions

TABLE AS-1.3  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	MC-1D	MC-3S	MC-3I	MC-3D
Lab Sample I.D.	970133A-13	970133A-14	970133A-15	970133A-16
Arsenic	60.0U	164.	6.0U	6.0U
Calcium	416000	18600	22600	104000
Chromium	80.2B	1.6B	1.0U	1.0U
Copper	NR	NR	NR	NR
Iron	455000	11100	9040	10400
Magnesium	139000	2660B	4780B	22300
Potassium	110000E	1160BE	2940BE	16100E
Sodium	1540000E	8580E	27800E	127000E
Zinc	NR	NR	NR	NR

See Appendix for qualifier definitions

TABLE AS-1.4  
7097-0133A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	GW-2	GW-5		
Lab Sample I.D.	970133A-01	970133A-09		
Arsenic	NR	NR		
Calcium	NR	NR		
Chromium	NR	NR		
Copper	5440	74.4		
Iron	NR	NR		
Magnesium	NR	NR		
Potassium	NR	NR		
Sodium	NR	NR		
Zinc	952.	411.		

See Appendix for qualifier definitions

Contract:

: GW-2

SDG No.: A0133

Lab Sample ID: 0133001

0.0

Date Received: 01/21/97

[illegible]

Comments: misc-cc1 = DOC  
misc-cc2 = Ferrous Iron  
misc-cc3 = Trivalent Chromium

MC-25

LL Name: IEA

Contract:

Lab Code: IEA

Case No.: 0133A

SAS No. :

SDG No.: A0153

Matrix: (soil/water) WATER

Lab Sample ID: 0133004

% Solids:

0.0

Date Received: 01/22/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron

Contract:

1 MC-21

SDG No.: A0133

Lab Sample ID: 0133005

0.0

Date Received: 01/22/97

[illegible]

FORM I - WC

1. Name: IEA

Contract:

MC-2D

Lab Code: IEA

Case No.: 0133A

SAS No. :

SDG No.: A0133

Matrix: (soil/water) WATER

Lab Sample ID: 0133006

% Solids: 0.0

Date Received: 01/22/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc

misc-cc 2 = Ferrous Iron

: GW-5

L. Name: IEA

Contract: \_\_\_\_\_

Lab Code: IEA

Case No.: 0133A

SAS No. : \_\_\_\_\_

SDG No.: A0133

Matrix: (soil/water) WATER

Lab Sample ID: 0133009

% Solids: 0.0

Date Received: 01/22/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron  
misc-cc3 = Trivalent Chromium

L-1 Name: IEA

Contract:

MC-19

Lab Code: IEA

Case No.: 0133A

SAS No. :

SDG No.: A0133

Matrix: (soil/water) WATER

Lab Sample ID: 0133010

% Solids:

0.0

Date Received: 01/23/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc

misc-cc2 = Ferrous Iron

Contract:

MC-1 I

SDG No.: A0133

Lab Sample ID: 0133011

Date Received: 01/23/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

```
Comments: misc-cc1 = Doc
          misc-cc2 = Ferrous Iron
```

Contract: \_\_\_\_\_

: MC-1D

SDG No.: A0133

Lab Sample ID: 0133013

Q.0

Date Received: 01/23/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron

Contract:

SDG No.: A0133

Lab Sample ID: 0133014

Date Received: 01/23/97

[illegible]

Comments: Misc-cc1 = Doc  
Misc-cc2 = Ferrous Iron

Contract: \_\_\_\_\_

SDG No.: A0133

Lab Sample ID: 0133015

Date Received: 01/23/97

[illegible]

FORM I - WC

1 MC-3D

SDG No.: A0133

Lab Sample ID: 0133016

Date Received: 01/23/97

[illegible]

FORM I - WC

## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).

## INORGANICS APPENDIX

### C - Concentration qualifiers

- U - Indicates analyte was not detected at method reporting limit.
- B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

- E - Reported value is estimated because of the presence of interference
- M - Duplicate injection precision not met
- N - Spiked sample recovery not within control limits
- S - The reported value was determined by the method of standard additions (MSA)
- W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance
- \* - Duplicate analysis not within control limit
- + - Correlation coefficient for MSA is less than 0.995

### M - Method codes

- P - ICP
- A - Flame AA
- F - Furnace AA
- CV - Cold vapor AA (manual)
- C - Cyanide
- NR - Not Required
- NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non-Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/Hazardous Waste	263

7097-0133A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

CLIENT ID	LAB ID	MATRIX	DATE COLLECTED	DATE RECEIVED
GW-2	970133A-01	WATER	01/20/97	01/21/97
FB-01/20	970133A-02	WATER	01/20/97	01/21/97
TB-01/20	970133A-03	WATER	01/20/97	01/21/97
MC-2S	970133A-04	WATER	01/21/97	01/22/97
MC-2I	970133A-05	WATER	01/21/97	01/22/97
MC-2D	970133A-06	WATER	01/21/97	01/22/97
FB-01/21	970133A-07	WATER	01/21/97	01/22/97
TB-01/21	970133A-08	WATER	01/21/97	01/22/97
GW-5	970133A-09	WATER	01/21/97	01/22/97
MC-1S	970133A-10	WATER	01/22/97	01/23/97
MC-1I	970133A-11	WATER	01/22/97	01/23/97
MC-1I	970133A-11D	WATER	01/22/97	01/23/97
MC-1I	970133A-11MS	WATER	01/22/97	01/23/97
MC-1I	970133A-11MSD	WATER	01/22/97	01/23/97
MC-1I	970133A-11S	WATER	01/22/97	01/23/97
MC-1I/R	970133A-12	WATER	01/22/97	01/23/97
MC-1D	970133A-13	WATER	01/22/97	01/23/97
MC-3S	970133A-14	WATER	01/22/97	01/23/97
MC-3I	970133A-15	WATER	01/22/97	01/23/97
MC-3D	970133A-16	WATER	01/22/97	01/23/97
TB-01/22	970133A-17	WATER	01/22/97	01/23/97

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: GW-2, FB-01/20, TB-01/20, MC-2S, MC-2I, MC-2D, FB-01/21, TB-01/21, GW-5, MC-1S, MC-1I, MC-1I/R, MC-1D, MC-3S, MC-3I, MC-3D, TB-01/22, MC-1I ...

Job Number: 7097-0133A

Date: 2/20/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
2	WATER	AMMONIA-350.2	Ammonia		
11	WATER	BICARBONATE-406C	Bicarbonate		
11	WATER	CARBONATE-2320B	Carbonate		
3	WATER	CC-MISC	Miscellaneous Classi		
1	WATER	CHLORIDE-325.2	Chloride		
1	WATER	CR6-SW846	Hexavalent Chromium		
11	WATER	FLUORIDE-340.2	Fluoride		
2	WATER	MET-SW846-MISC	Miscellaneous Metals		
16	WATER	MET-SW846-MISC-D	Miscellaneous Metals		
2	WATER	NITRATE-353.2	Nitrate-Nitrogen		
2	WATER	NITRITE-353.2	Nitrite-Nitrogen		
11	WATER	SULFATE-375.4	Sulfate		
11	WATER	SULFIDE-376.1	Sulfide		
11	WATER	TOC-9060-DUP	Total Organic Carbon		
19	WATER	VOA-CLP3.1-MISC	Miscellaneous Volati		

/

## APPENDIX B

## **APPENDIX B**

### **Sediment-Quality Analytical Data Reports**



**IEA**  
An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

February 24, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
1377 Motor Parkway  
Islandia, NY 11788

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 10 samples received at our laboratory on January 24, 1997. This report contains sections addressing the following information at a minimum:

- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

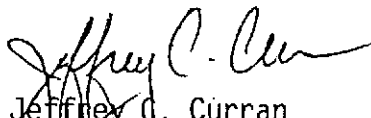
IEA Report #	7097-0177A
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,

  
Jeffrey C. Curran  
Laboratory Manager

JCC

Schaumburg,  
Illinois  
847-705-0740

N. Billerica,  
Massachusetts  
508-667-1400

Whippany,  
New Jersey  
201-428-8181

Cary,  
North Carolina  
919-677-0090



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**7097-0177A**  
**ROUX ASSOCIATES**

**Case Narrative**

**Classical Chemistry.** Listed below are the Classical Chemistry methods and references for all samples analyzed in this SDG. Total sulfur will be sent as an addendum. No problems were encountered and all holding times were met.

Analyte	Method	Reference
Eh	D-1498	2
pH	9045	1
Hexavalent Chromium	7196	1
AVS	EPA 821/R-90-100	3
TOCD	9060	1

**References:**

1. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.
2. USACOE "Method for Oxidation-Reduction Potential of Water and Sediment Samples."
3. USEPA, Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, 1983.

**Metals** - ICAP metals were determined using a JA61E trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3050/6010.

No problems occurred during analysis. All appropriate protocols were employed. All data appears to be consistent.

IEC's are electronically employed by the TJA ICAP-61 and ICAP JA61E trace. However, the ICSA is utilized as a monitoring device to detect any additional adjustments that may be required. These modifications are calculated and applied manually. They are so noted in the raw data.

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5972A GC/MS/DS.

No problems were encountered.

TABLE VO-1.0  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	Method Blank	SED3/0-0.5	SED3/0-0.5 MS	Quant. Limits with no Dilution
Lab Sample I.D.	VLKDS	970177A-01	970177A-01MS	
Method Blank I.D.	VLKDS	VLKDS	VLKDS	
Quant. Factor	1.00	1.45	1.45	
Benzene	U	U	64X	10
Toluene	U	2J	76X	10
Date Received		01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.1  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	SED3/0-0.5 MSD 970177A-01	SED3/0.5-1 MSD 970177A-02	SED3/1-1.5 MSD 970177A-03	Quant. Limits with no Dilution
Lab Sample I.D.	MSD	MSD	MSD	
Method Blank I.D.	VLKDS	VLKDS	VLKDS	
Quant. Factor	1.45	1.26	1.23	
Benzene	63X	U	U	10
Toluene	74X	2J	U	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.2  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	SED3/1.5-2	SED3/2-2.5	SED4/0-0.5	Quant. Limits with no Dilution
Lab Sample I.D.	970177A-04	970177A-05	970177A-06	
Method Blank I.D.	VLK8	VLK8	VLK8	
Quant. Factor	1.25	1.23	3.85	
Benzene	U	U	U	10
Toluene	U	U	U	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.3  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	SED4/0.5-1	SED4/1-1.5	SED4/1.5-2	Quant. Limits with no Dilution
Lab Sample I.D.	970177A-07	970177A-08	970177A-09	
Method Blank I.D.	VLKDS	VLKDS	VLKDS	
Quant. Factor	3.57	3.22	4.00	
Benzene	U	U	U	10
Toluene	U	U	U	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE AS-1.0  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY

Soil

All values are mg/Kg dry weight basis.

Client Sample I.D.	SED3/0-0.5	SED3/0-0.5 D	SED3/0-0.5 S	SED3/0.5-1
Lab Sample I.D.	970177A-01	970177A-01D	970177A-01S	970177A-02
Arsenic	35.2	29.3	45.1	13.3
Chromium	26.3	23.2	71.8	6.4

See Appendix for qualifier definitions

TABLE VO-1.4  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	SED4/2-2.5			Quant. Limits with no Dilution
Lab Sample I.D.	970177A-10			
Method Blank I.D.	VBLKD8			
Quant. Factor	1.30			
Benzene	U			10
Toluene	2J			10
Date Received	01/24/97			
Date Extracted	N/A			
Date Analyzed	01/30/97			

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE AS-1.1  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY

Soil

All values are mg/Kg dry weight basis.

Client Sample I.D.	SED3/1-1.5	SED3/1.5-2	SED3/2-2.5	SED4/0-0.5
Lab Sample I.D.	970177A-03	970177A-04	970177A-05	970177A-06
Arsenic	11.7	7.7	12.5	419.
Chromium	6.0	3.8	6.1	664.

See Appendix for qualifier definitions

TABLE AS-1.2  
7097-0177A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY

Soil

All values are mg/Kg dry weight basis.

Client Sample I.D.	SED4/0.5-1	SED4/1-1.5	SED4/1.5-2	SED4/2-2.5
Lab Sample I.D.	970177A-07	970177A-08	970177A-09	970177A-10
Arsenic	397.	603.	503.	56.6
Chromium	517.	983.	910.	56.7

See Appendix for qualifier definitions

SED3/0-0.5

SDG No.: A0177

Lab Sample ID: 0177001

Date Received: 01/24/97

[illegible]

FORM I - WC

Contract: \_\_\_\_\_

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

Comments:  $\text{misc-cc1} = \text{AVS} \quad \mu\text{mole/g}$   
 $\text{misc-cc2} = \text{EH} \quad \text{mV}$

SED3/1-1.5

SDG No.: A0177

Lab Sample ID: 0177003

77.1

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

1420.

$m_{SC-CC2} = EH \quad mV$

Contract: \_\_\_\_\_

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments:  $\text{misc-cc1} = \text{AVS} \quad \frac{\mu\text{mole}}{\text{g}}$   
 $\text{misc-cc2} = \text{EH} \quad \frac{\text{mV}}{\text{mV}}$

Contract: \_\_\_\_\_

SDG No. : A0177

Lab Sample ID: Q177005

Date Received: 01/24/97

[illegible]

FORM I - WC

Contract:

SED4/0-0.5

SDG No.: A0177

Lab Sample ID: 0177006

30.8

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: misc-cc1 AVS umole/g  
misc-cc2 EH mv

Contract:

SED4/0.5-1

SDG No.: A0177

Lab Sample ID: 0177007

24.5

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

Comments:  $\text{misc-cc1} = \text{AVS}$   $\text{wmode} / \text{g}$   
 $\text{misc-cc2} = \text{EH}$   $\text{mv}$

L-4 Name: IEA

Contract:

SED4/1-1.5

Lab Code: IEA

Case No.: 0177A

SAS No. :

SDG No.: A0177

Matrix: (soil/water) SOIL

Lab Sample ID: 0177008

% Solids:

26.2

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: misc-cc1 = AVS umole/g  
misc-cc2 = EH mv

SED4/1.5-2

SDG No.: A0177

Lab Sample ID: 0177009

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments:  $\text{misc-cc1} = \text{AVS}$        $w_{\text{male}}/g$   
 $\text{misc-cc2} = \text{EH}$        $\text{mv}$

Contract: \_\_\_\_\_

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments:  $\text{misc-cc1} = \text{AVS}$   $\text{umole/g}$   
 $\text{misc-cc2} = \text{EH}$   $\text{mV}$

## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).

## INORGANICS APPENDIX

### C - Concentration qualifiers

- U - Indicates analyte was not detected at method reporting limit.
- B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

- E - Reported value is estimated because of the presence of interference
- M - Duplicate injection precision not met
- N - Spiked sample recovery not within control limits
- S - The reported value was determined by the method of standard additions (MSA)
- W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance
- \* - Duplicate analysis not within control limit
- + - Correlation coefficient for MSA is less than 0.995

### M - Method codes

- P - ICP
- A - Flame AA
- F - Furnace AA
- CV - Cold vapor AA (manual)
- C - Cyanide
- NR - Not Required
- NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/ Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/ Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non- Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/ Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/ Hazardous Waste	263

7097-0177A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

CLIENT ID	LAB ID	MATRIX	DATE COLLECTED	DATE RECEIVED
SED3/0-0.5	970177A-01	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01D	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01MS	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01MSD	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01S	SOIL	01/23/97	01/24/97
SED3/0.5-1	970177A-02	SOIL	01/23/97	01/24/97
SED3/1-1.5	970177A-03	SOIL	01/23/97	01/24/97
SED3/1.5-2	970177A-04	SOIL	01/23/97	01/24/97
SED3/2-2.5	970177A-05	SOIL	01/23/97	01/24/97
SED4/0-0.5	970177A-06	SOIL	01/23/97	01/24/97
SED4/0.5-1	970177A-07	SOIL	01/23/97	01/24/97
SED4/1-1.5	970177A-08	SOIL	01/23/97	01/24/97
SED4/1.5-2	970177A-09	SOIL	01/23/97	01/24/97
SED4/2-2.5	970177A-10	SOIL	01/23/97	01/24/97

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: SED3/0-0.5, SED3/0.5-1, SED3/1-1.5, SED3/1.5-2, SED3/2-2.5,  
SED4/0-0.5, SED4/0.5-1, SED4/1-1.5, SED4/1.5-2, SED4/2-2.5,  
SED3/0-0.5, SED3/0-0.5, SED3/0-0.5, SED3/0-0.5  
Job Number: 7097-0177A

Date: 2/24/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
10	SOIL	CC-MISC	Miscellaneous Classi		
10	SOIL	CR6-SW846	Hexavalent Chromium		
12	SOIL	MET-SW846-MISC	Miscellaneous Metals		
10	SOIL	PH-9045	pH		
9	SOIL	TOC-9060-DUP	Total Organic Carbon		
2	SOIL	VOA-CLP3.1-MISC	Miscellaneous Volati		



**IEA**  
An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

April 8, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
13 Branch Street  
Suite 13  
Methuen, MA 01844

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 10 samples received at our laboratory on January 24, 1997. This report contains sections addressing the following information at a minimum:

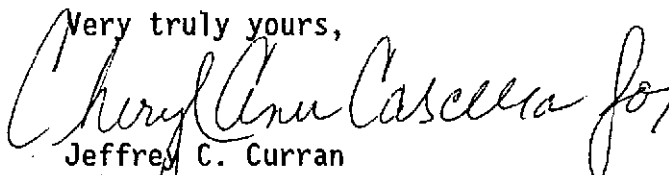
- . sample summary
- . analytical methodology
- . state certifications
- . definitions of data qualifiers and terminology
- . analytical results
- . chain-of-custody

IEA Report #7097-0177A Addendum	Purchase Order #06626Y08
Project ID: Woburn, MA	

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We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,  
  
Jeffrey C. Curran  
Laboratory Manager

JCC/ab



7097-0177A Addendum  
ROUX ASSOCIATES

Case Narrative

Classical Chemistry - Ten samples were analyzed for total Sulfur following ASTM method D129. No analytical problems were encountered.

Contract: \_\_\_\_\_

SDG No.: <sup>R</sup>80177

Lab Sample ID: 0177101

Date Received: 01/24/97

[illegible]

Comments: \* Total Sulfur %

2 Name: TEA

**Contract:**

SED3/0.5-1

Lab Code: IEA

Case No.: 01778

SAS No. :

SDG No.: A0177

Matrix: (soil/water) SOIL

Lab Sample ID: 0177102

% Solids:

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: \* Total Sulfur %

Contract: \_\_\_\_\_

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: \* Total Sulfur %

Contract: \_\_\_\_\_

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: \* Total Sulfur %

Contract: \_\_\_\_\_

Date Received: 01/24/97

[illegible]

Comments: \*Total Sulfur . %

Gefaszet: \_\_\_\_\_

~~Contract:~~ \_\_\_\_\_

SED4/1-1.5

Letter Name: IEA

Contract: \_\_\_\_\_

Lab Code: IEA

Case No.: 0177A

SAS No. : \_\_\_\_\_

SDG No.: B0177

Matrix: (soil/water) SOIL

Lab Sample ID: 0177108-

% Solids:

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: \* Total Sulfur %

Contract: \_\_\_\_\_

SED4/2-2.5

Lab Name: IEA

Contract: \_\_\_\_\_

Lao Code: IEA

Case No.: 0177A

SAS No. :

SDG No.: B0177

Matrix: (soil/water) SOIL

Lab Sample ID: 0177110 -

% Solids:

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

Comments: \* Total Sulfur %

## STATE CERTIFICATIONS

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State	Responsible Agency	Certification	Lab Number
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Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non-Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/Hazardous Waste	263

## INORGANICS APPENDIX

### C - Concentration qualifiers

U - Indicates analyte was not detected at method reporting limit.

B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

E - Reported value is estimated because of the presence of interference

M - Duplicate injection precision not met

N - Spiked sample recovery not within control limits

S - The reported value was determined by the method of standard additions (MSA)

W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance

\* - Duplicate analysis not within control limit

+ - Correlation coefficient for MSA is less than 0.995

### M - Method codes

P - ICP

A - Flame AA

F - Furnace AA

CV - Cold vapor AA (manual)

C - Cyanide

NR - Not Required

NC - Not Calculated as per protocols

7097-0177A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

CLIENT ID	LAB ID	MATRIX	DATE COLLECTED	DATE RECEIVED
SED3/0-0.5	970177A-01	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01D	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01MS	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01MSD	SOIL	01/23/97	01/24/97
SED3/0-0.5	970177A-01S	SOIL	01/23/97	01/24/97
SED3/0.5-1	970177A-02	SOIL	01/23/97	01/24/97
SED3/1-1.5	970177A-03	SOIL	01/23/97	01/24/97
SED3/1.5-2	970177A-04	SOIL	01/23/97	01/24/97
SED3/2-2.5	970177A-05	SOIL	01/23/97	01/24/97
SED4/0-0.5	970177A-06	SOIL	01/23/97	01/24/97
SED4/0.5-1	970177A-07	SOIL	01/23/97	01/24/97
SED4/1-1.5	970177A-08	SOIL	01/23/97	01/24/97
SED4/1.5-2	970177A-09	SOIL	01/23/97	01/24/97
SED4/2-2.5	970177A-10	SOIL	01/23/97	01/24/97

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: SED3/0-0.5, SED3/0.5-1, SED3/1-1.5, SED3/1.5-2, SED3/2-2.5,  
SED4/0-0.5, SED4/0.5-1, SED4/1-1.5, SED4/1.5-2, SED4/2-2.5,  
SED3/0-0.5, SED3/0-0.5, SED3/0-0.5, SED3/0-0.5  
Job Number: 7097-0177A

Date: 4/8/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
10	SOIL	CC-MISC	Miscellaneous Classi		
10	SOIL	CR6-SW846	Hexavalent Chromium		
12	SOIL	MET-SW846-MISC	Miscellaneous Metals		
10	SOIL	PH-9045	pH		
10	SOIL	TOC-9060-DUP	Total Organic Carbon		
12	SOIL	VOA-CLP3.1-MISC	Miscellaneous Volati		



# IEA

An Aquarion Company

American Environmental Network

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

May 02, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
13 Branch Street  
Suite 13  
Methuen, MA 01844

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 3 samples received at our laboratory on April 11, 1997. This report contains sections addressing the following information at a minimum:

- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

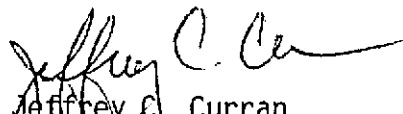
IEA Report #	7097-0818A
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,

  
Jeffrey C. Curran  
Laboratory Manager

JCC

Schaumburg,  
Illinois  
847-705-0740

N. Billerica,  
Massachusetts  
508-667-1400

Whippany,  
New Jersey  
201-428-8181

Cary,  
North Carolina  
919-677-0090



printed on recycled paper

**7097-0818A**  
**ROUX ASSOCIATES**

**Case Narrative**

**Metals** - ICAP metals were determined using a JA61E trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3050/6010.

No problems occurred during analysis. All appropriate protocols were employed. All data appears to be consistent.

IEC's are electronically employed by the JA61E trace ICAP. However, the ICSA is utilized as a monitoring device to detect any additional adjustments that may be required. These modifications are calculated and applied manually. They are so noted in the raw data.

**Classical Chemistry.** Listed below are the Classical Chemistry methods and references for all samples analyzed in this SDG. Eh reported as misc-cc. No problems were encountered.

Analyte	Method	Reference
Eh	D-1498	2
pH	9045	1
Hexavalent Chromium	7196	1
TOCD	9060	1

**References:**

1. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.
2. USACOE "Method for Oxidation-Reduction Potential of Water and Sediment Samples."

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5972A GC/MS/DS.

No problems were encountered.

**Miscellaneous Classical Chemistry** - Subcontracted to Schwarzkopf Microanalytical Laboratory, Inc.

TABLE VO-1.0  
7097-0818A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	Method Blank	SED1 0-1.5'	SED1 1 .5-2.5'	Quant. Limits with no Dilution
Lab Sample I.D.	VLKDR	970818A-01	970818A-02	
Method Blank I.D.	VLKDR	VLKDR	VLKDR	
Quant. Factor	1.00	34.5	1.23	
Benzene	U	4100	34	10
Toluene	U	U	2J	10
Date Received		04/11/97	04/11/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	04/14/97	04/14/97	04/14/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.1  
7097-0818A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Soil

All values are ug/Kg dry weight basis.

Client Sample I.D.	Method Blank	SED2 0-0.5'		
Lab Sample I.D.	VELKDS	970818A-03		Quant. Limits with no Dilution
Method Blank I.D.	VELKDS	VELKDS		
Quant. Factor	1.00	9.09		
Benzene	U	400		10
Toluene	U	14J		10
Date Received		04/11/97		
Date Extracted	N/A	N/A		
Date Analyzed	04/15/97	04/15/97		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE AS-1.0  
7097-0818A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY

Soil

All values are mg/Kg dry weight basis.

Client Sample I.D.	SED1 0-1.5'	SED1 1 .5-2.5'	SED2 0-0.5'	
Lab Sample I.D.	970818A-01	970818A-02	970818A-03	
Arsenic	1390	18.3	1270	
Chromium	1060	15.0	711.	

See Appendix for qualifier definitions

Contract:

SED1 0-1.5'

SAS No. :

SDG No.: A0818

Lab Sample ID: 0818001

Date Received: 04/11/97

[illegible]

Comments: \*EH

Contract: \_\_\_\_\_

:SED1 1.5-2.5'

SDG No.: A0818

Lab Sample ID: 0818002

Date Received: 04/11/97

[illegible]

Comments: \*EH

Contract:

SED2 0-0.5'

SDG No.: A0818

Lab Sample ID: 0818003

14.6

Date Received: 04/11/97

Concentration Units (mg/L or mg/kg dry weight) : mg/Kg

[illegible]

\* EH

Comments: \_\_\_\_\_

SCHWARZKOPF MICROANALYTICAL LABORATORY, INC.

56-19 37th Ave.  
Woodside, N.Y. 11377  
Tel. 718-429-6248  
Fax. 718-397-7144

Frank E Maple, Pres.  
Florence Wohl, Exec V.P.

Mary Donnelly  
IEA

Date:  
4/30/97  
Report#  
9520805

RESULTS OF ANALYSIS

*Sed. 1 (0-1.5)*      *Sed. 1 (1.5-2.5)*      *Sed. 2 (0-0.5)*

	SAMPLE #	SAMPLE #	SAMPLE #
	970818A-01	970818A-02	970818A-03
	SML#	SML#	SML#
	D79647	D79648	D79649
% Acid Volatile Sulfide	0.11	15 ppm	0.076
% Total Sulfur	0.30	0.034	0.070

SCHWARZKOPF MICROANALYTICAL LABORATORY, INC.

*Edmund Petro*  
Edmund Petro  
Technical Director

## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).

## INORGANICS APPENDIX

### C - Concentration qualifiers

- U - Indicates analyte was not detected at method reporting limit.
- B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

- E - Reported value is estimated because of the presence of interference
- M - Duplicate injection precision not met
- N - Spiked sample recovery not within control limits
- S - The reported value was determined by the method of standard additions (MSA)
- W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance
- \* - Duplicate analysis not within control limit
- + - Correlation coefficient for MSA is less than 0.995

### M - Method codes

- P - ICP
- A - Flame AA
- F - Furnace AA
- CV - Cold vapor AA (manual)
- C - Cyanide
- NR - Not Required
- NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/ Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/ Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non- Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/ Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/ Hazardous Waste	263

7097-0818A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

[illegible]

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: SED1 0-1.5', SED1 1.5-2.5', SED2 0-0.5'  
Job Number: 7097-0818A

Date: 5/2/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
3	SOIL	CC-MISC	Miscellaneous Classi		
3	SOIL	CR6-SW846	Hexavalent Chromium		
3	SOIL	MET-SW846-MISC	Miscellaneous Metals		
3	SOIL	PH-9045	pH		
3	SOIL	TOC-9060-DUP	Total Organic Carbon		
3	SOIL	VOA-CLP3.1-MISC	Miscellaneous Volati		



## APPENDIX C

## **APPENDIX C**

### **X-Ray Fluorescence Data**

: 8:30:31 DATE: 4/27/97

0-1.5

CA	21959.641	PPM	+/-	560.8279
TI	2308.952	PPM	+/-	145.0519
V	110.342	PPM	+/-	39.9016
CR	545.977	PPM	+/-	36.9616
MN	971.094	PPM	+/-	56.3770
FE	143550.031	PPM	+/-	262.6755
NI	53.495	PPM	+/-	22.3355
CU	1371.936	PPM	+/-	24.8020
AS	1352.365	PPM	+/-	9.9688
PB	772.558	PPM	+/-	12.3310
AG	1.454	PPM	+/-	1.2950
CD	61.598	PPM	+/-	1.9749
SB	32.281	PPM	+/-	2.5533
BA	456.613	PPM	+/-	9.0003
ZN	16298.964	PPM	+/-	59.9622
BR	22.057	PPM	+/-	4.8218
SIO2	81.013	DIFF		
SIO2	0.000	DIFF		

0-0.5

CA	12119.531	PPM	+/-	544.9937
TI	2198.777	PPM	+/-	158.4527
V	10.654	PPM	+/-	43.4208
CR	106.894	PPM	+/-	35.2146
MN	1412.082	PPM	+/-	51.0194
FE	66579.547	PPM	+/-	178.7244
NI	N D			
CU	188.311	PPM	+/-	12.3322
AS	113.031	PPM	+/-	3.0512
PB	106.731	PPM	+/-	4.9553
AG	1.038	PPM	+/-	0.7887
CD	9.331	PPM	+/-	0.8668
SB	N D			
BA	450.890	PPM	+/-	7.1996
ZN	2384.781	PPM	+/-	20.9956
BR	8.371	PPM	+/-	1.9331
SIO2	91.431	DIFF		
SIO2	0.000	DIFF		



## **APPENDIX D**

### **Electron-Microscopy Data and Photomicrographs**

Sample Id: SED 1

Date: 5-1-97

Start Time: 1:45

Finish: 3:40

	Phase	Length	Notes
	FeO (no As or Cu)		
	FeSO (no As or Cu)	10	spherical
	(As) FeSSiAlO (K)	1000 +	0.18% As
	(As) FeKNaCaAlSiSO	900	
	"		0.25% As
	(As) FeSO		
(Photo 1)	(As) FeZnCaSO		1.99% As
	(As) FeCuSO (Pb)		
	(As) FeZnSO	100	1.80% As
dot map	(As) CaMgAlSiO Fe		
photo 24	(As) FeAlSO	5	6.4% As
	(As) ZnFeSO SiAl	60	
photo 45	(As) (Zn) FeCaKSSiAlO	1000 +	
	(As) FeSiAlNaO	150	intermingled with SiO (no As)
	(As) FeSO	1000 +	
	(As) FeAlSiSO KCa	1000 +	
	(As) FeMgAlSiO <del>(no As)</del>	200	intermingled with SiO (No As)
	(As) FeMgAlSiO	150	platy
	(As) FeCaAlSiMgSO	300	
	(As) (Zn) FeCaKSSiAlO	1000 +	
	"	1000 +	
	(As) FeAlSiMgO	130	platy
	(As) FeO	60	hind, original grain is gone
	(As) FeKMgAlSiO	140	platy (prob biotite)
	(As) MgFe(Ca)SiO	250	
	(As) Fe(Ca)SSiAlO (Zn)	210	
	(As) FeCaSO	210	
	(As) FeCaSSiAlO	260	
	(As) FeCaSO	1000 +	
	(As) FeCaMgSiO	230	platy
	(As) Fe(Mg)SiAlO	200	platy
	"	80	"
	(As) FeKMgAlSiO	90	"

Sample Id: SED 4 0.5-1

Date: 4-22-97

Start Time:

Finish:

Phase	Length
(As)(Fe Mg) Ca SiO	200
(As)(Mg) Fe Al SiO	200
(As)(Fe Mg) Ca Si AlO	80
(As) FeO	95
KAlSiO (No As)	180
(As) FeO	80
KAlSiO (No As)	500
" "	150
" "	200
(As) Fe K Mg Al SiO (Ca)	200
(As) Fe K Mg Al SiO	160
KAlSiO (No As)	220
(As) Fe Ca Mg SiO	130
(As) Fe K Mg Al SiO	300

Notes
Included in KAlSiO
" "
very porous
platy (muscovite?)
porous
platy
"
"
platy (biotite?)
" "
platy (muscovite?)
platy (biotite?)

Sample Id: SED 4 1-1.5

Start Time: 10:30

Date: 4-22-97

Finish: 11:30

<u>Phase</u>		<u>Length</u>	<u>Notes</u>
(As)(Fe)(Mg)CaAlSiO		300	0.08 % As
"		75	
(As)FeO		15	
(As)CaMgSiO		1000	
(As)(Fe,Mg)CaAlSiO		~6000	
(As)(Fe,Mg)CaAlSiO		800	
Photo 4 (As)(Fe)(Mg)CaAlSiO		600	
"		300	porous grain 0.2 % As

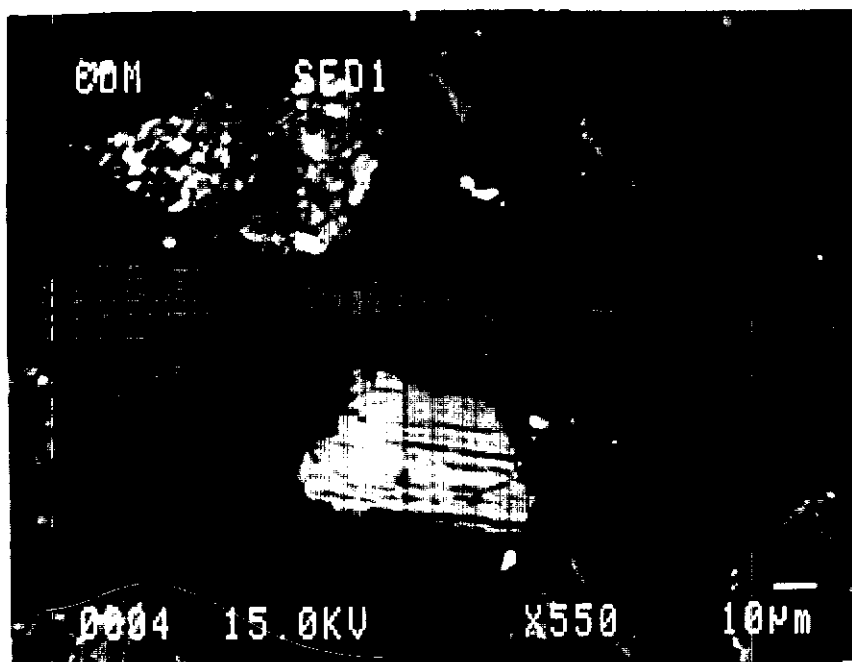
Sample Id: SED 4 - 1.5-2

Date: 4-22-97

Start Time: 1:00

Finish: 4:00

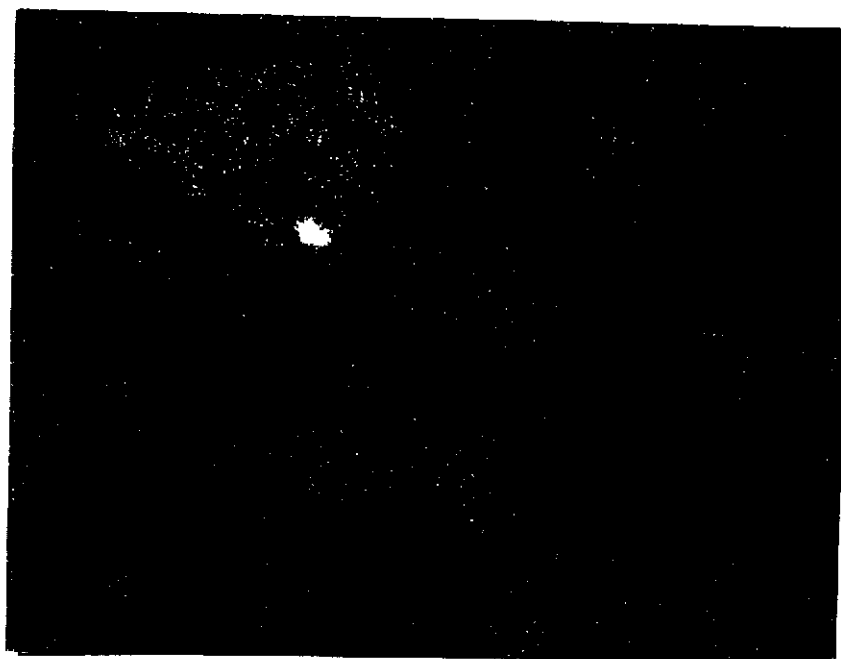
	Phase	Length	Notes
	(As) Fe K Mg Al Si O		
photo 5	(As) Fe Ca (Ti) Al Mg Si O	> 1,000	0.15% As
	(As) Fe Ca Mg Al Si O	250	
	"	350	platy
photo 6	"	375	platy 0.07% As
	(As) Fe Mg Al Si O	275	partially included (Na) Ca Al Si O in
	(As) Fe Ca Mg Al Si O	210	
	(As) Fe K Mg Al Si O	400	platy
	(As) Fe Ti Zn Al O	100	
	(As) Fe Mg Al Si O	700	0.30% As
	(As) (K, Ca, Ti) Fe Mg Al Si O	300	platy
	(As) Fe Ca Mg Al Si O	85	
photo 7	{ (As) Fe Mg Al Si O (Ca, Ti, K)	600	platy (biotite?) attached to Ca Al Si O
	(As) Fe Mg Al Si O	200	platy; attached to K Al Si O
	(As) Fe K Mg Al Si O	180	platy
photo 8	(As) Fe K Mg Al Si O	varies	intermingled with quartz
	(As) Fe Mg Al Si O	50	hundreds of similar grains in >1000 nm matrix of SiO
	Fe O (No As or Cr)	230	secondary prod.
	(As) Fe Ca Mg Al Si O	40	Including ilmenite
			Hundreds of grains, most associated with ilmenite and Fe Mg Al Si O
	Fe O (No As or Cr)	130	porous
	(As) K Fe Mg Al Si O		along with crystalline Fe O and Ca Si Al O, comprises grain >1000, muscovite?
	K Al Si O (No As)	250	
	"	120	"
	(As) K Fe Mg Al Si O	95	platy
	(As) Fe Mg Al Si O (Ca, Ti)	250	platy



**Photomicrograph 1**

SED 1

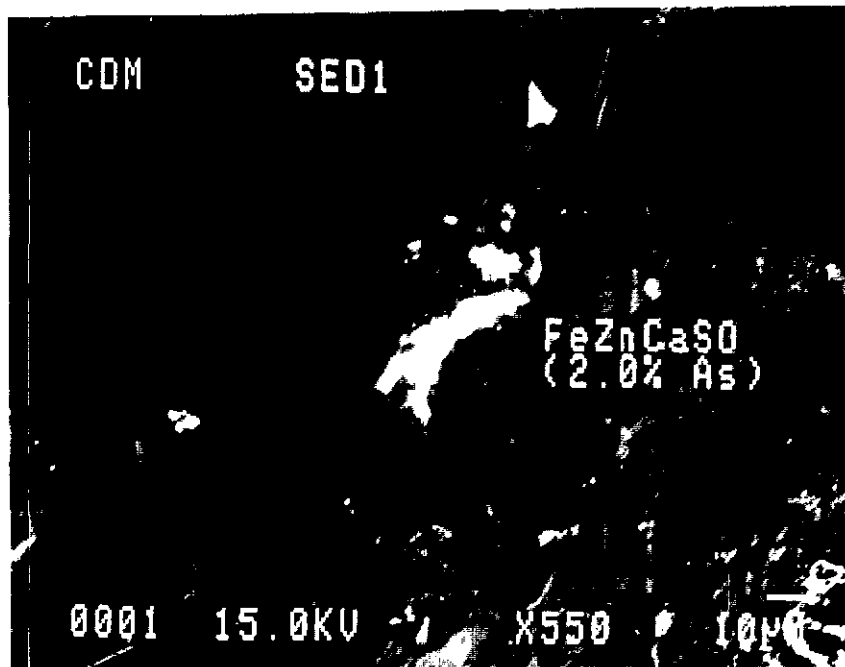
Backscatter image showing a particle of iron/aluminum sulfate containing 6.4% arsenic and two grains of biotite containing approximately 0.2% arsenic.



**Photomicrograph 2**

SED 1

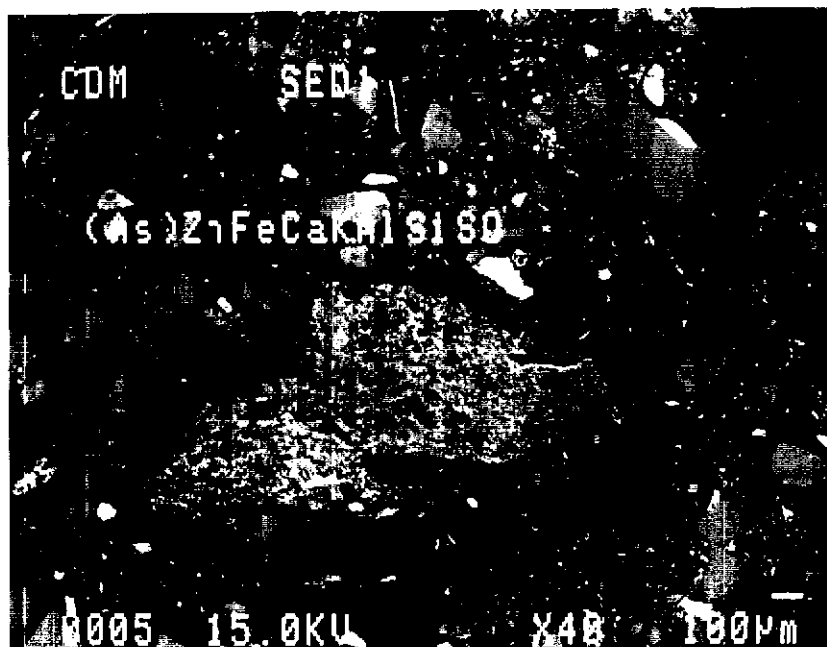
Arsenic concentration map (Dot map) showing the same frame as in photomicrograph 1. Note the higher density of dots on the iron/aluminum sulfate and biotite grains.



**Photomicrograph 3**

SED 1

Backscatter image showing a grain of iron/calcium/zinc sulfate containing 2% arsenic.



**Photomicrograph 4**

SED 1

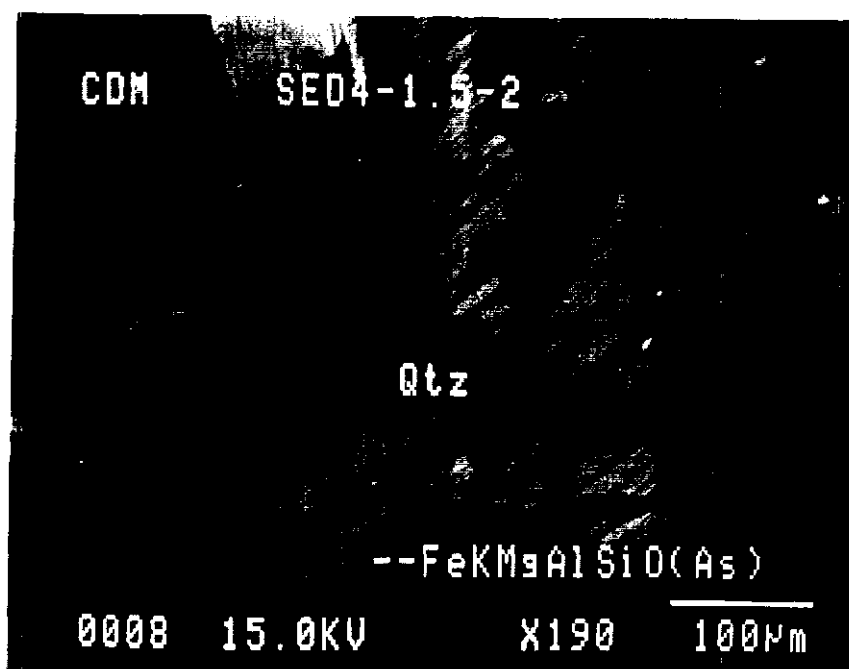
Backscatter image showing a mass of aluminosilicate and quartz grains cemented by an arsenic-bearing iron/calcium/zinc sulfate.



Photomicrograph 5

SED 4

Backscatter image showing a biotite or clay grain containing 0.07% arsenic.



Photomicrograph 6

SED 4

Backscatter image showing arsenic bearing biotite grains intergrown with quartz.



Photomicrograph 7

SED 4

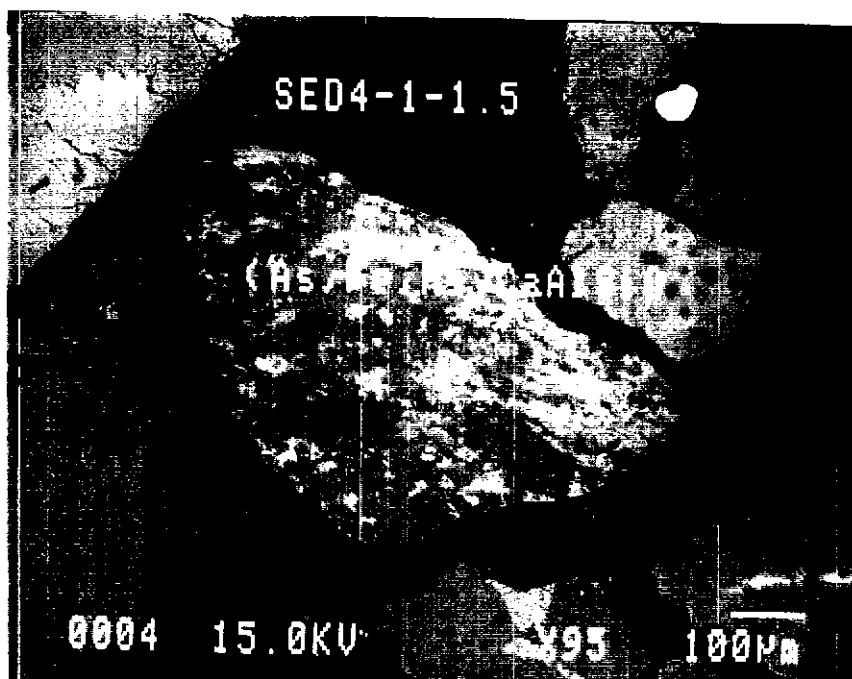
Backscatter image showing an arsenic-bearing biotite grain



Photomicrograph 8

SED 4

Backscatter image showing an amphibole or pyroxene grain  
containing 0.15% arsenic.



**Photomicrograph 9**

SED 4

Backscatter image showing an arsenic - bearing silicate mineral.



## **APPENDIX E**

### **Surface-Water Quality Analytical Data Report**



**IEA**  
An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

February 24, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
1377 Motor Parkway  
Islandia, NY 11788

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 19 samples received at our laboratory on January 23-24, 1997. This report contains sections addressing the following information at a minimum:

- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

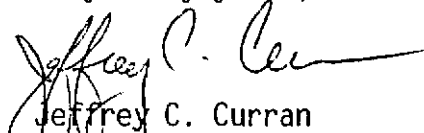
IEA Report #	7097-0154A
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,

  
Jeffrey C. Curran  
Laboratory Manager

JCC



7097-0154A  
ROUX ASSOCIATES

Case Narrative

**Metals** - ICAP metals were determined using a JA61 simultaneous ICAP and a JA61E trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3010/6010.

Two "E" flags resulted from serial dilution analysis of sample SW-5/F for potassium and sodium. There is no apparent reason for these flags.

No other problems occurred during analysis. All appropriate protocols were employed. All data appears to be consistent.

IEC's are electronically employed by the TJA ICAP-61 and ICAP JA61E trace. However, the ICSA is utilized as a monitoring device to detect any additional adjustments that may be required. These modifications are calculated and applied manually. They are so noted in the raw data.

**Classical Chemistry** - Listed below are the wet chemistry analyte methods and references for the samples analyzed in this SDG. Misc-cc 1 reported as DOC and misc-cc 2 reported as ferrous iron. No analytical problems were encountered and all holding times were met.

Analyte	Method	Reference
Bicarbonate	2320B	2
Carbonate	2320B	2
Chloride	325.2	1
Fluoride	340.2	1
DOC	9060	3
Ferrous Iron	3500-Fe D	2
Sulfide	376.1	1
Sulfate	375.4	1
TOCD	9060	3

**References:**

1. Methods of Chemical Analysis of Water and Wastes, EPA 600, 1983.
2. Standard Methods for the Examination of Water and Wastewater. 18th edition, 1992.
3. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5972A GC/MS/DS.

No problems were encountered.

TABLE VO-1.0  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	SW-5	SW-5/F	Quant. Limits with no Dilution
Lab Sample I.D.	VBLKD7	970154A-01	970154A-02	
Method Blank I.D.	VBLKD7	VBLKD7	VBLKD7	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	4J	10
Toluene	U	U	U	10
Date Received		01/23/97	01/23/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/29/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.1  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-6	SW-6/F		
Lab Sample I.D.	970154A-03	970154A-04		Quant. Limits
Method Blank I.D.	VLKD7	VLKD7		with no
Quant. Factor	1.00	1.00		Dilution
Benzene	U	U		10
Toluene	U	U		10
Date Received	01/23/97	01/23/97		
Date Extracted	N/A	N/A		
Date Analyzed	01/30/97	01/30/97		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.2  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	FB-01/22	SW-3	Quant. Limits with no Dilution
Lab Sample I.D.	VLKLD9	970154A-05	970154A-08	
Method Blank I.D.	VLKLD9	VLKLD9	VLKLD9	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	U	U	2J	10
Date Received		01/23/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.3  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-3/F	SW-4	SW-4/F	Quant. Limits with no Dilution
Lab Sample I.D.	970154A-09	970154A-10	970154A-11	
Method Blank I.D.	VLK9	VLK9	VLK9	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	1J	U	U	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/31/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.4  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-1S	SW-1S/F	SW-1I	Quant. Limits with no Dilution
Lab Sample I.D.	970154A-12	970154A-13	970154A-14	
Method Blank I.D.	VLK9	VLK9	VLK9	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	1J	1J	2J	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/31/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.5  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-1I/F	SW-1D	SW-1D/F	Quant. Limits with no Dilution
Lab Sample I.D.	970154A-15	970154A-16	970154A-17	
Method Blank I.D.	VLK9	VLK9	VLK9	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	1J	1J	1J	10
Date Received	01/24/97	01/24/97	01/24/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/31/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.6  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	TB-01/23	FB-01/23		Quant. Limits with no Dilution
Lab Sample I.D.	970154A-18	970154A-19		
Method Blank I.D.	VLKDD9	VLKDD9		
Quant. Factor	1.00	1.00		
Benzene	U	U		10
Toluene	U	U		10
Date Received	01/24/97	01/24/97		
Date Extracted	N/A	N/A		
Date Analyzed	01/30/97	01/30/97		

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE AS-1.0  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-5/F	SW-6/F	SW-3/F	SW-4/F
Lab Sample I.D.	970154A-06	970154A-07	970154A-09	970154A-11
Arsenic	6.0U	6.0U	6.0U	6.0U
Calcium	32100	30600	34400	31300
Chromium	1.0U	1.0U	1.0U	1.0U
Iron	660.	273.	472.	560.
Magnesium	5790	5760	5870	5380
Potassium	4650BE	5980E	5780E	5330E
Sodium	50100E	46100E	49600E	48500E

See Appendix for qualifier definitions

TABLE AS-1.1  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-1S/F	SW-1I/F	SW-1D/F	
Lab Sample I.D.	970154A-13	970154A-15	970154A-17	
Arsenic	6.0U	8.2B	18.1	
Calcium	30500	34400	41500	
Chromium	1.0U	1.0U	1.3B	
Iron	358.	320.	1210	
Magnesium	5370	5700	7160	
Potassium	5100E	5430E	5560E	
Sodium	43900E	48000E	49400E	

See Appendix for qualifier definitions

TABLE AS-1.2  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-5	SW-6	FB-01/22	SW-3
Lab Sample I.D.	970154A-01	970154A-03	970154A-05	970154A-08
Arsenic	8.2B	6.0U	6.0U	14.2
Calcium	31800	33400	NR	33000
Chromium	1.4B	3.1B	1.0U	4.8B
Iron	1430	1140	NR	2240
Magnesium	5800	6020	NR	5720
Potassium	4660BE	6560E	NR	5670E
Sodium	50200E	46400E	NR	48800E

See Appendix for qualifier definitions

TABLE AS-1.3  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-4	SW-1S	SW-1I	SW-1D
Lab Sample I.D.	970154A-10	970154A-12	970154A-14	970154A-16
Arsenic	7.8B	7.1B	13.9	51.8
Calcium	31900	30400	36000	42800
Chromium	3.7B	2.0B	1.9B	14.6
Iron	2030	1100	1460	3660
Magnesium	5470	5270	6010	7490
Potassium	5420E	4980BE	5840E	5760E
Sodium	48900E	43300E	50300E	50300E

See Appendix for qualifier definitions

TABLE AS-1.4  
7097-0154A  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	FB-01/23			
Lab Sample I.D.	970154A-19			
Arsenic	6.0U			
Calcium	NR			
Chromium	1.0U			
Iron	NR			
Magnesium	NR			
Potassium	NR			
Sodium	NR			

See Appendix for qualifier definitions

Contract:

: SW-5

SDG No. : A0154

Lab Sample ID: 0154001

Date Received: 01/23/97

[illegible]

Comments: misc-cc2 = Ferrous Iron

Contract: \_\_\_\_\_

Contract: \_\_\_\_\_

Date Received: 01/23/97

[illegible]

FORM I - WC

L' Name: IEA

Contract:

SW-6 / F

Lab Code: IEA

Case No.: 0154A

SAS No. :

SDG No.: A0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154004

% Solids: 0.0

Date Received: 01/23/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = DOC  
misc-cc2 = Ferrous Iron

Contract:

SDG No.: AQ154

Lab Sample ID: Q154006

Date Received: 01/24/97

[illegible]

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Contract: \_\_\_\_\_

Lab Name: IEA

Contract: \_\_\_\_\_

SW-3

Lab Code: IEA

Case No.: 0154A

SAS No. :

SDG No.: A0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154008

% Solids: 0.0

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: MISC-CC2 = Ferrous Iron

SW-3/F

SDG No.: A0154

Lab Sample ID: 0154009

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron



Contract: \_\_\_\_\_

SW-4/F

SDG No.: A0154

Lab Sample ID: 0154011

0.0

Date Received: 01/24/97

[illegible]

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron

Contract:

ST-15

SDG No.: A0154

Lab Sample ID: 0154012

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc2 = Ferrous Iron

Contract: \_\_\_\_\_

Contract: \_\_\_\_\_

Date Received: 01/24/97

[illegible]

FORM I - WC

Contract:

SW-11/F

SDG No.: A0154

Lab Sample ID: Q154Q15

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

Comments: misc-cc1 = POC  
misc-cc2 = Ferrous Iron

L-5 Name: IEA

Contract: \_\_\_\_\_

: SW-1D

Lab Code: IEA

Case No.: 0154A

SAS No. : \_\_\_\_\_

SDG No.: A0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154016

% Solids: 0.0

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc2 = Ferrous Iron

Lab Name: IEA

Contract: \_\_\_\_\_

SW-1D/F

Lab Code: IEA

Case No.: 0154A

SAS No. :

SDG No.: A0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154017

% Solids:

0.0

Date Received: 01/24/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: misc-cc1 = Doc  
misc-cc2 = Ferrous Iron

## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).

## INORGANICS APPENDIX

### C - Concentration qualifiers

U - Indicates analyte was not detected at method reporting limit.

B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

E - Reported value is estimated because of the presence of interference

M - Duplicate injection precision not met

N - Spiked sample recovery not within control limits

S - The reported value was determined by the method of standard additions (MSA)

W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance

\* - Duplicate analysis not within control limit

+ - Correlation coefficient for MSA is less than 0.995

### M - Method codes

P - ICP

A - Flame AA

F - Furnace AA

CV - Cold vapor AA (manual)

C - Cyanide

NR - Not Required

NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non-Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/Hazardous Waste	263

7097-0154A  
ROUX ASSOCIATES  
SAMPLE SUMMARY

CLIENT ID	LAB ID	MATRIX	DATE COLLECTED	DATE RECEIVED
SW-5	970154A-01	WATER	01/22/97	01/23/97
SW-5/F	970154A-02	WATER	01/22/97	01/23/97
SW-6	970154A-03	WATER	01/22/97	01/23/97
SW-6/F	970154A-04	WATER	01/22/97	01/23/97
FB-01/22	970154A-05	WATER	01/22/97	01/23/97
SW-5/F	970154A-06	WATER	01/22/97	01/24/97
SW-6/F	970154A-07	WATER	01/22/97	01/24/97
SW-3	970154A-08	WATER	01/23/97	01/24/97
SW-3/F	970154A-09	WATER	01/23/97	01/24/97
SW-4	970154A-10	WATER	01/23/97	01/24/97
SW-4/F	970154A-11	WATER	01/23/97	01/24/97
SW-1S	970154A-12	WATER	01/23/97	01/24/97
SW-1S/F	970154A-13	WATER	01/23/97	01/24/97
SW-1I	970154A-14	WATER	01/23/97	01/24/97
SW-1I/F	970154A-15	WATER	01/23/97	01/24/97
SW-1D	970154A-16	WATER	01/23/97	01/24/97
SW-1D/F	970154A-17	WATER	01/23/97	01/24/97
TB-01/23	970154A-18	WATER	01/23/97	01/24/97
FB-01/23	970154A-19	WATER	01/23/97	01/24/97

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: SW-5, SW-5/F, SW-6, SW-6/F, FB-01/22, SW-5/F, SW-6/F, SW-3, SW-3/F, SW-4, SW-4/F, SW-1S, SW-1S/F, SW-1I, SW-1I/F, SW-1D, SW-1D/F, TB-01/23 ...

Job Number: 7097-0154A

Date: 2/24/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
14	WATER	BICARBONATE-406C	Bicarbonate		
14	WATER	CARBONATE-2320B	Carbonate		
14	WATER	CC-MISC	Miscellaneous Classi		
14	WATER	CHLORIDE-325.2	Chloride		
1	WATER	FLUORIDE-340.2	Fluoride		
9	WATER	MET-SW846-MISC	Miscellaneous Metals		
7	WATER	MET-SW846-MISC-D	Miscellaneous Metals		
14	WATER	SULFATE-375.4	Sulfate		
14	WATER	SULFIDE-376.1	Sulfide		
7	WATER	TOC-9060-DUP	Total Organic Carbon		
17	WATER	VOA-CLP3.1-MISC	Miscellaneous Volati		



# IEA

An Aquarion Company

200 Monroe Turnpike  
Monroe, Connecticut 06468

Phone 203-261-4458  
Fax 203-268-5346

February 24, 1997

Mr. Larry Mctiernan  
ROUX ASSOCIATES  
1377 Motor Parkway  
Islandia, NY 11788

Dear Mr. Mctiernan:

Please find enclosed the analytical results of 9 samples received at our laboratory on January 25, 1997. This report contains sections addressing the following information at a minimum:

- . sample summary
- . analytical methodology
- . state certifications
- . definition of data qualifiers and terminology
- . analytical results
- . chain-of-custody

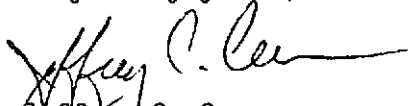
IEA Report #	7097-0154B
Project ID:	Woburn, MA
Purchase Order #	06626Y08

Copies of this analytical report and supporting data are maintained in our files for a minimum of five years unless special arrangements have been made. Unless specifically indicated, all analytical testing was performed at this laboratory location and no portion of the testing was subcontracted.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (203) 261-4458 for any additional information. Thank you for utilizing our services; we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Very truly yours,

  
Jeffrey C. Curran  
Laboratory Manager

JCC



**7097-0154B**  
**ROUX ASSOCIATES**

**Case Narrative**

Classical Chemistry - Listed below are the wet chemistry analyte methods and references for the samples analyzed in this SDG. Misc-cc 1 reported as DOC and Misc-cc 2 reported as ferrous iron. No analytical problems were encountered and all holding times were met.

Analyte	Method	Reference
Bicarbonate	2320B	2
Carbonate	2320B	2
Chloride	325.2	1
Fluoride	340.2	1
DOC	9060	3
Ferrous Iron	3500-Fe D	2
Sulfide	376.1	1
Sulfate	375.4	1
TOCD	9060	3

**References:**

1. Methods of Chemical Analysis of Water and Wastes, EPA 600, 1983.
2. Standard Methods for the Examination of Water and Wastewater. 18th edition, 1992.
3. Test Methods for the Evaluation of Solid Wastes, SW846, 3rd ed., 1986.

**Metals** - ICAP metals were determined using a JA61 simultaneous ICAP and a JA61E trace ICAP using guidance provided in SW846 according to the following Methods: ICAP-3010/6010.

Two "E" flags resulted from serial dilution analysis of sample SW-2D for potassium and sodium. There is no apparent reason for these flags.

No other problems occurred during analysis. All appropriate protocols were employed. All data appears to be consistent.

IEC's are electronically employed by the TJA ICAP-61 and ICAP JA61E trace. However, the ICSCA is utilized as a monitoring device to detect any additional adjustments that may be required. These modifications are calculated and applied manually. They are so noted in the raw data.

**Volatile Organics** - Volatile organics were determined by purge and trap GC/MS using USEPA CLP Protocols, OLM03.1. The instrumentation used was a Tekmar Dynamic Headspace Concentrator interfaced with a Hewlett-Packard Model 5995 GC/MS-DS.

No problems were encountered.

TABLE VO-1.0  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	Method Blank	SW-2S	SW-2S/F	Quant. Limits with no Dilution
Lab Sample I.D.	VLKG4	970154B-01	970154B-02	
Method Blank I.D.	VLKG4	VLKG4	VLKG4	
Quant. Factor	1.00	1.00	1.00	
Benzene	U	U	U	10
Toluene	U	1J	1J	10
Date Received		01/25/97	01/25/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/30/97	01/30/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
 Quant. Factor = a numerical value which takes into account any variation in sample weight/volume, % moisture and sample dilution.

TABLE VO-1.1  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2I	SW-2I/F	SW-2D/F	Quant. Limits with no Dilution
Lab Sample I.D.	970154B-03	970154B-04	970154B-05	
Method Blank I.D.	VBKLG4	VBKLG4	VBKLG4	
Quant. Factor	1.00	1.00	1.00	
Benzene	2J	6J	57	10
Toluene	1J	1J	2J	10
Date Received	01/25/97	01/25/97	01/25/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/31/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.2  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2D	SW-2D MS	SW-2D MSD 970154B-06	Quant. Limits with no Dilution
Lab Sample I.D.	970154B-06	970154B-06MS	MSD	
Method Blank I.D.	VLKG4	VLKG4	VLKG4	
Quant. Factor	1.00	1.00	1.00	
Benzene	80	120X	130X	10
Toluene	2J	45X	48X	10
Date Received	01/25/97	01/25/97	01/25/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/31/97	01/31/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE VO-1.3  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS VOLATILE ORGANICS

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2D/R	FB-01/24	TB-01/24	Quant. Limits with no Dilution
Lab Sample I.D.	970154B-07	970154B-08	970154B-09	
Method Blank I.D.	VBKLG4	VBKLG4	VBKLG4	
Quant. Factor	1.00	1.00	1.00	
Benzene	69	U	U	10
Toluene	25	U	U	10
Date Received	01/25/97	01/25/97	01/25/97	
Date Extracted	N/A	N/A	N/A	
Date Analyzed	01/31/97	01/30/97	01/30/97	

See Appendix for qualifier definitions

Note: Compound detection limit = quantitation limit x quantitation factor  
Quant. Factor = a numerical value which takes into account any  
variation in sample weight/volume, % moisture and  
sample dilution.

TABLE AS-1.0  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Dissolved)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2S/F	SW-2I/F	SW-2D/F	
Lab Sample I.D.	970154B-02	970154B-04	970154B-05	
Arsenic	6.0U	6.0U	33.9	
Calcium	30300	50000	105000	
Chromium	1.0U	1.0B	5.0B	
Iron	316.	199.	18300	
Magnesium	5110	7670	17400	
Potassium	4860BE	6270E	10400E	
Sodium	42200E	50600E	81800E	

See Appendix for qualifier definitions

TABLE AS-1.1  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2S	SW-2I	SW-2D	SW-2D D
Lab Sample I.D.	970154B-01	970154B-03	970154B-06	970154B-06D
Arsenic	6.9B	11.7	617.	658.
Calcium	28300	46800	94300	NR
Chromium	1.1B	1.4B	225.	237.
Iron	944.	1310	52800	NR
Magnesium	4850B	7290	16200	NR
Potassium	4640BE	6180E	10000E	NR
Sodium	40500E	50400E	74100E	NR

See Appendix for qualifier definitions

TABLE AS-1.2  
7097-0154B  
ROUX ASSOCIATES  
MISCELLANEOUS ATOMIC SPECTROSCOPY (Total)

Aqueous

All values are ug/L.

Client Sample I.D.	SW-2D S	SW-2D/R	FB-01/24	
Lab Sample I.D.	970154B-06S	970154B-07	970154B-08	
Arsenic	715.	2880	6.0U	
Calcium	NR	NR	NR	
Chromium	417.	390.	1.0U	
Iron	NR	NR	NR	
Magnesium	NR	NR	NR	
Potassium	NR	NR	NR	
Sodium	NR	NR	NR	

See Appendix for qualifier definitions

Contract:

SW-2S

SDG No.: E0154

Lab Sample ID: Q154101

Date Received: 01/25/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: MISC-CC2 = Ferrous Iron

' 5 Name: IEA

Contract:

SW-25/F

LA Code: IEA

Case No.: 01548

SAS No. :

SDG No.: B0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154102

% Solids: 0.0

Date Received: 01/25/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: MISC-CCI = Doc

misc-cc2 = Ferrous Iron

Contract:

:SW-2I

SDG No. : B0154

Lab Sample ID: 0154103

Date Received: 01/25/97

[illegible]

Comments: Misc-cc2 = Ferrous Iron

SW-21/F

SDG No.: B0154

Lab Sample ID: 0154104

Date Received: 01/25/97

[illegible]

Comments: misc-cc1 = DOC  
misc-cc2: Ferrous Iron

Name: IEA

Contract: \_\_\_\_\_

SW-2D/F

Lab Code: IEA

Case No.: 0154E

SAS No. :

SDG No.: B0154

Matrix: (soil/water) WATER

Lab Sample ID: 0154105

% Solids:

0.0

Date Received: 01/25/97

Concentration Units (mg/L or mg/kg dry weight) : mg/L

[illegible]

Comments: MISC-CC1 = Doc

misc-cc2 = Ferrous Iron

Contract: \_\_\_\_\_

Date Received: 01/25/97

[illegible]

FORM I - WC

## ORGANICS APPENDIX

- U - Indicates that the compound was analyzed for but not detected.
- J - Indicates that the compound was analyzed for and determined to be present in the sample. The mass spectrum of the compound meets the identification criteria of the method. The concentration listed is an estimated value, which is less than the specified minimum detection limit but is greater than zero.
- B - This flag is used when the analyte is found in the blanks as well as the sample. It indicates possible sample contamination and warns the data user to use caution when applying the results of this analyte.
- N - Indicates that the compound was analyzed for but not requested as an analyte. Value will not be listed on tabular result sheet.
- S - Estimated due to surrogate outliers.
- X - Matrix spike compound.
- (1) - Cannot be separated.
- (2) - Decomposes to azobenzene. Measured and calibrated as azobenzene.
- A - This flag indicates that a TIC is a suspected aldol condensation product.
- E - Indicates that it exceeds calibration curve range.
- D - This flag identifies all compounds identified in an analysis at a secondary dilution factor.
- C - Confirmed by GC/MS.
- T - Compound present in TCLP blank.
- P - This flag is used for a pesticide/aroclor target analyte when there is a greater than 25 percent difference for detected concentrations between the two GC columns (see Form X).

## INORGANICS APPENDIX

### C - Concentration qualifiers

- U - Indicates analyte was not detected at method reporting limit.
- B - Indicates analyte result between IDL and contract required detection limit (CRDL)

### Q - QC qualifiers

- E - Reported value is estimated because of the presence of interference
- M - Duplicate injection precision not met
- N - Spiked sample recovery not within control limits
- S - The reported value was determined by the method of standard additions (MSA)
- W - Post-digest spike recovery furnace analysis was out of 85-115 percent control limit, while sample absorbance was less than 50 percent of spike absorbance
- \* - Duplicate analysis not within control limit
- + - Correlation coefficient for MSA is less than 0.995

### M - Method codes

- P - ICP
- A - Flame AA
- F - Furnace AA
- CV - Cold vapor AA (manual)
- C - Cyanide
- NR - Not Required
- NC - Not Calculated as per protocols

## STATE CERTIFICATIONS

In some instances it may be necessary for environmental data to be reported to a regulatory authority with reference to a certified laboratory. For your convenience, the laboratory identification numbers for the IEA-Connecticut laboratory are provided in the following table. Many states certify laboratories for specific parameters or tests within a category (i.e. method 325.2 for wastewater). The information in the following table indicates the lab is certified in a general category of testing such as drinking water or wastewater analysis. The laboratory should be contacted directly if parameter-specific certification information is required.

### IEA-Connecticut Certification Summary (as of December 1996)

State	Responsible Agency	Certification	Lab Number
Connecticut	Department of Health Services	Drinking Water, Wastewater	PH-0497
Kansas	Department of Health and Environmental Services	Drinking Water, Wastewater/Solid, Hazardous Waste	E-210/E-1185
Massachusetts	Department of Environmental Protection	Potable/Non-Potable Water	CT023
New Hampshire	Department of Environmental Services	Drinking Water, Wastewater	252891
New Jersey	Department of Environmental Protection	Drinking Water, Wastewater	46410
New York	Department of Health	CLP, Drinking Water, Wastewater, Solid/ Hazardous Waste	10602
North Carolina	Division of Environmental Management	Wastewater	388
North Dakota	Department of Health and Consolidated Laboratories	Non-Potable/Potable Hazardous Waste	R-138
Oklahoma	Department of Environmental Quality	General Water Quality/ Sludge Testing	9614
Rhode Island	Department of Health	Chemistry...Non- Potable Water and Wastewater	A43
Washington	Department of Ecology	Wastewater/ Hazardous Waste	C231
West Virginia	Division of Environmental Protection	Wastewater/ Hazardous Waste	263

7097-0154B  
ROUX ASSOCIATES  
SAMPLE SUMMARY

[illegible]

## IEA-CT ANALYTICAL SUMMARY

Page:1

Client ID: SW-2S, SW-2S/F, SW-2I, SW-2I/F, SW-2D/F, SW-2D, SW-2D, SW-2D,  
SW-2D, SW-2D, SW-2D/R, FB-01/24, TB-01/24  
Job Number: 7097-0154B

Date: 2/24/97

Qty	Matrix	Analysis	Description	Unit Price	Total Price
6	WATER	BICARBONATE-406C	Bicarbonate		
6	WATER	CARBONATE-2320B	Carbonate		
6	WATER	CC-MISC	Miscellaneous Classi		
6	WATER	CHLORIDE-325.2	Chloride		
5	WATER	FLUORIDE-340.2	Fluoride		
7	WATER	MET-SW846-MISC	Miscellaneous Metals		
3	WATER	MET-SW846-MISC-D	Miscellaneous Metals		
6	WATER	SULFATE-375.4	Sulfate		
6	WATER	SULFIDE-376.1	Sulfide		
3	WATER	TOC-9060-DUP	Total Organic Carbon		
11	WATER	VOA-CLP3.1-MISC	Miscellaneous Volati		



## **APPENDIX F**

### **July 1997 HBHA Surface-Water Monitoring Report**

August 26, 1997

Mr. Michael House  
The Chemical Group of Monsanto Company  
800 N. Lindbergh Boulevard  
St. Louis, Missouri 63167

Subject: Data Report for July 1997 Water Quality Determination  
HBHA Monitoring Program, ISRT, Woburn, Massachusetts.

Dear Mr. House:

Geraghty & Miller, Inc. (Geraghty & Miller) completed water quality determination activities at two locations within the outlet channel of the Hall's Brook Holding Area (HBHA) at the ISRT site in Woburn, Massachusetts on Monday, July 21, 1997. The water quality determination activities included the measurement of field parameters and the collection of surface water samples for laboratory analysis from two locations within the HBHA outlet channel. Sampling location #1 was where the outlet channel connects to the HBHA. Sampling location #2 was where the outlet channel crosses Mishawum Road. The sampling locations are shown on Figure 1.

The results of the field parameters testing are as follows:

**Location #1:**

Dissolved Oxygen (DO)	=	3.6 mg/L
Temperature	=	21.8 °C
Oxidation Reduction Potential (Eh)	=	312 mV
pH	=	7.1 standard units
Conductivity	=	332 µS
Estimated Total Flow Rate	=	2.1 cu. ft./sec

**Location #2:**

Dissolved Oxygen (DO)	=	5.2 mg/L
Temperature	=	22.6 °C
Oxidation Reduction Potential (Eh)	=	232 mV
pH	=	7.2 standard units
Conductivity	=	416 µS
Estimated Total Flow Rate	=	0.9 cu. ft./sec



Mr. Michael House

August 26, 1997

Page 2

Geraghty & Miller collected an unfiltered surface water sample and a field-filtered surface water sample from both sampling locations within the HBHA outlet channel. Geraghty & Miller also collected an unfiltered replicate surface water sample and a field-filtered replicate surface water sample from both sampling locations within the HBHA outlet channel. The samples were analyzed by IEA Laboratories Inc. of Billerica, Massachusetts. The Dissolved Metals analyses were conducted on the field-filtered samples. The Total Metals, Volatile Aromatics, and Total Suspended Solids analyses were conducted on the unfiltered samples. The required preservatives were added in advance by the analytical laboratory and the bottles were not overflowed during the sample collection activities. Results from the laboratory analytical testing are summarized as follows:

**Location #1:**Dissolved Metals

Arsenic	0.0112 mg/L
Chromium	BQL (<0.03 mg/L)

Total Metals

Arsenic	0.0287 mg/L
Chromium	BQL (<0.03 mg/L)

Volatile Aromatics

Benzene	BQL (<1 µg/L)
Toluene	BQL (<1 µg/L)
Total Suspended Solids	4.8 mg/L

**Location #1 (Replicate Sample):**Dissolved Metals

Arsenic	0.0098 mg/L
Chromium	BQL (<0.03 mg/L)

Total Metals

Arsenic	0.0252 mg/L
Chromium	BQL (<0.03 mg/L)

Volatile Aromatics

Benzene	BQL (< 1 µg/L)
Toluene	BQL (<1 µg/L)
Total Suspended Solids	5.9 mg/L



Mr. Michael House  
August 26, 1997  
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**Location #2:****Dissolved Metals**

Arsenic	0.0098 mg/L
Chromium	BQL (<0.03 mg/L)

**Total Metals**

Arsenic	0.0302 mg/L
Chromium	BQL (<0.03 mg/L)

**Volatile Aromatics**

Benzene	BQL (<1 µg/L)
Toluene	BQL (<1 µg/L)

Total Suspended Solids	11.3 mg/L
------------------------	-----------

**Location #2 (Replicate Sample):****Dissolved Metals**

Arsenic	0.0118 mg/L
Chromium	BQL (<0.03 mg/L)

**Total Metals**

Arsenic	0.0296 mg/L
Chromium	BQL (<0.03 mg/L)

**Volatile Aromatics**

Benzene	BQL (< 1 µg/L)
Toluene	BQL (<1 µg/L)

Total Suspended Solids	10.6 mg/L
------------------------	-----------

BQL = Below Quantitation Limit

The analytical data reports, the QA/QC reports and the BTEX analysis chromatograms provided by the laboratory are included as Appendix A. Geraghty & Miller has reviewed the BTEX analysis chromatograms and the laboratory QA/QC data for the Method 8020 analysis and has concluded that the laboratory's interpretations relative to compound identifications and concentration quantitations are appropriate.



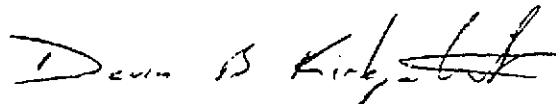
Mr. Michael House  
August 26, 1997  
Page 4

Table 1.1 presents the historical data collected from sampling location #1. Table 1.2 presents the historical data collected from sampling location #2. Plots for the historical analytical data which are intended to illustrate long-term trends in the concentration data are included as Appendix B. For plotting purposes, samples with concentrations below the quantitation limit are represented as being at the quantitation limit. Calculations and assumptions used during the estimation of the total flowrate at each sampling point are included as Appendix C.

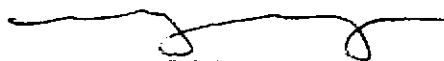
If you have any questions or concerns, please do not hesitate to call Devin Kirkpatrick at (508) 794-9470.

Sincerely,

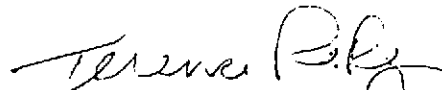
GERAGHTY & MILLER, INC.



Devin B. Kirkpatrick, P.E.  
Project Engineer/Project Manager



E. W. Peter Jalajas  
Senior Scientist



Terence R. Regan  
Associate/Project Officer

cc: ISRT



Table 1. Data Summary  
 Sampling Location #1  
 Halls Brook Holding Area, Woburn, MA.

Parameter	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jun-95 (Replicate)	Jul-95	Aug-95	Sep-95	Oct-95	Oct-95 (Replicate)	Nov-95	Dec-95	Jan-96	Feb-96
Total Arsenic (mg/L)	0.0114	0.0155	0.0107	0.0143	0.0127	0.0130	0.0159	0.0192	0.0123	0.0212	0.0186	0.0206	0.0145	0.0174	0.0138
Dissolved Arsenic (mg/L)	0.0097	0.0093	0.0059	0.0076	0.0063	0.0054	< 0.005	< 0.005	< 0.005	0.0085	0.0087	0.0148	0.0095	0.0132	0.0108
Total Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Dissolved Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Benzene (ug/L)	4	4	5	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	4	< 1	4	3
Toluene (ug/L)	8	8	4	< 1	2	2	< 1	< 1	< 1	< 1	< 1	10	6	5	10
Total Suspended Solids (mg/L)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Dissolved Oxygen (mg/L)	7.1	3.3	NM	7.3	5.7	-	3.8	5.4	5.9	6.3	-	6.9	6.6	6.4	5.8
Temperature (°C)	1.7	9.5	14.5	19.2	26.0	-	29.1	22.8	22.0	16.4	-	5.6	1.0	1.6	4.8
pH (standard units)	6.1	7.1	6.9	6.8	7.4	-	7.3	6.6	6.7	6.6	-	6.6	6.1	7.8	7.1
Oxidation Reduction Potential (mV)	236	-24 **	-18 **	-38 **	165	-	140	170	25	200	-	310	245	200	290
Conductivity (uS)	NM	NM	NM	NM	NM	-	NM	1202	1060	403	-	432	NM	557	104.7
Surface Elevation (feet above m.s.l.)	55.28	55.08	55.20	54.87	54.57	-	54.36	54.30	54.32	54.83	-	55.18	55.02	55.42	55.10
Total Flow (cfs)	4.8	4.0	4.5	1.9	0.9	-	0.5	0.4	0.7	1.2	-	2.0	1.4	3.2	1.9

NM Not Measured

\*\* Malfunction of field instrument suspected.



Table 1. Data Summary  
 Sampling Location #1  
 Halls Brook Holding Area, Woburn, MA.

Parameter	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Jul-96 (Replicate)	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96	Jan-97	Jan-97 (Replicate)	Feb-97	Mar-97
Total Arsenic (mg/L)	0.0183	0.0189	0.0521	NM	0.0109	0.0195	0.0173	0.0209	0.018	0.0079	0.0168	0.0112	0.0090	0.0106	0.0207
Dissolved Arsenic (mg/L)	0.0143	0.0085	0.0078	NM	0.0071	0.0051	< 0.005	0.0103	0.0062	0.0079	0.0121	0.0067	0.0061	0.0085	0.0122
Total Chromium (mg/L)	< 0.030	< 0.030	< 0.030	NM	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Dissolved Chromium (mg/L)	< 0.030	< 0.030	< 0.030	NM	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Benzene (ug/L)	3	< 1	< 1	NM	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	2	5
Toluene (ug/L)	10	5	< 1	NM	2	2	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1
Total Suspended Solids (mg/L)	NM	10.6	11.8	NM	6.6	6.8	4.0	5.2	4.8	4.0	3.0	2.8	3.2	3.2	5.4
Dissolved Oxygen (mg/L)	7.0	NM	8.2	NM	NM	-	NM	4.6	4.2	4.4	4.1	6.6	-	7.2	6.4
Temperature (°C)	14.0	18.4	22.6	NM	23.9	-	24.0	15.7	13.8	7.0	5.0	2.0	-	5.1	2.5
pH (standard units)	6.7	6.9	6.7	NM	6.5	-	6.9	7.3	8.2	8.4	6.7	7.3	-	7.0	7.1
Oxidation Reduction Potential (mV)	245	270	205	NM	185	-	240	215	255	175	165	170	-	195	142
Conductivity (uS)	290	139	129	NM	112	-	198	82	89	102	79	79	-	85	87
Surface Elevation (feet above m.s.l.)	55.20	55.20	55.00	NM	54.50	-	54.25	55.05	54.62	55.25	55.50	55.60	-	55.20	55.20
Total Flow (cfs)	2.4	0.9	2.5	NM	0.7	-	0.5	7.0	2.9	7.4	9.0	4.0	-	3.7	8.9

NM Not Measured

\*\* Malfunction of field instrument suspected.



Table 1. Data Summary  
 Sampling Location #1  
 Halls Brook Holding Area, Woburn, MA.

Parameter	Apr-97	May-97	Jun-97	Jul-97	Jul-97 (Replicate)	Detection Limit	Detection Counts	Average (Mean)	Min	Max
Total Arsenic (mg/L)	0.0093	0.0147	0.0062	0.0287	0.0252	0.005	34	0.0167	0.0062	0.0521
Dissolved Arsenic (mg/L)	0.0061	0.0070	0.0113	0.0112	0.0098	0.005	30	0.0089	0.0051	0.0148
Total Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	0.030	0	< 0.030	< 0.030	< 0.030
Dissolved Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	0.030	0	< 0.030	< 0.030	< 0.030
Benzene (ug/L)	2	<1	<1	<1	<1	1	11	3.5	2	5
Toluene (ug/L)	<1	<1	<1	<1	<1	1	14	5.4	2	10
Total Suspended Solids (mg/L)	3.2	34.0	3.0	4.8	5.9	N/A	18	6.8	2.8	34
Dissolved Oxygen (mg/L)	5.2	5.0	5.4	3.6	-	N/A	25	5.7	3.3	8.2
Temperature (°C)	9.3	19.5	21.3	21.8	-	N/A	29	13.8	1	29.1
pH (standard units)	6.8	7.1	7	7.1	-	N/A	29	7.0	6.1	8.4
Oxidation Reduction Potential (mV)	190	272	220	312	-	N/A	26	209	25	312
Conductivity (uS)	181	167	155	332	-	N/A	22	276	79	1202
Surface Elevation (feet above m.s.l.)	55.20	55.15	54.80	54.50	-	N/A	29	55.0	54.3	55.6
Total Flow (cfs)	4.5	3.8	1.9	2.1	-	N/A	29	3.1	0.4	9

NM Not Measured

\*\* Malfunction of field instrument suspected.



Table 2 Data Summary  
 Sampling Location #2  
 Halls Brook Holding Area, Woburn, MA

Parameter	Aug-95	Sep-95	Oct-95	Oct-95 (Replicate)	Nov-95	Dec-95	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Jul-96 (Replicate)	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96
Total Arsenic (mg/L)	0.0154	0.0157	0.0150	0.0135	0.0137	0.0162	0.0108	0.0085	0.0176	0.0444	0.0214	0.0168	0.0098	0.0176	0.0179	0.0125	0.0110	0.0087	0.0074
Dissolved Arsenic (mg/L)	< 0.005	< 0.005	0.0054	0.0057	0.0088	0.0082	0.0098	0.0067	0.009	0.0051	0.0104	0.0057	< 0.005	< 0.005	< 0.005	0.0065	< 0.005	< 0.005	0.0061
Total Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	0.031	0.032	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Dissolved Chromium (mg/L)	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030	< 0.030
Benzene (ug/L)	< 1	< 1	< 1	< 1	< 1	< 1	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Toluene (ug/L)	< 1	< 1	< 1	< 1	2	3	2	5	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Total Suspended Solids (mg/L)	NM	NM	NM	NM	NM	NM	NM	NM	NM	140	218	56	68	68	82	26	32	82	26
Dissolved Oxygen (mg/L)	5.5	6.2	6.4	-	7.0	6.0	6.5	6.9	6.0	NM	7.9	6.0	NM	-	NM	5.0	3.3	3.8	4.6
Temperature (°C)	21.6	20.0	18.3	-	5.3	2.0	1.5	3.5	11.0	18.3	23.3	16.5	24.7	-	25.0	16.1	14.7	7.0	4.5
pH (standard units)	6.9	6.6	6.6	-	6.6	6.2	7.4	6.9	7.0	7.1	6.9	6.9	6.9	-	7.1	7.3	7.3	7.3	6.5
Oxidation Reduction Potential (mV)	130	25	225	-	300	165	250	225	200	220	250	245	260	-	275	280	280	125	140
Conductivity (uS)	1152	1065	443	-	175	NM	503	369	290	104	149	111	224	-	174	100	274	206	104
Surface Elevation	0.94	0.96	1.25	-	1.40	1.32	1.71	2.90	1.30	1.54	1.42	1.6	1.0	-	0.8	4.0	2.4	1.7	1.8
Total Flow (cfs)	1.5	0.9	0.8	-	1.9	1.2	7.6	3.3	2.4	3.3	3.0	2.6	1.1	-	0.6	5.2	5.1	7.0	5.2

NM Not Measured

Sampling program at Location #2 started in August 1995.

Surface elevation data for Location #2 is relative to the staff gauge elevation.



Table 2 Data Summary  
 Sampling Location #2  
 Halls Brook Holding Area, Woburn, MA

Parameter	Jan-97	Jan-97 (Replicate)	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Jul-97 (Replicate)	Detection Limit	Detection Counts	Average (Mean)	Min	Max
Total Arsenic (mg/L)	0.0111	0.0147	0.0066	0.0148	0.0056	0.0133	0.0149	0.0302	0.0296	0.005	28	0.0166	0.0056	0.0476
Dissolved Arsenic (mg/L)	0.0057	0.0062	<0.005	0.0100	<0.005	0.0061	0.0092	0.0098	0.0118	0.005	19	0.0077	0.0051	0.0118
Total Chromium (mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.030	0	<0.030	<0.030	0.032
Dissolved Chromium (mg/L)	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.030	0	<0.030	<0.030	<0.030
Benzene (ug/L)	<1	<1	<1	1	<1	<1	<1	<1	<1	<1	2	1.5	1	2
Toluene (ug/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	5	2.8	2	5
Total Suspended Solids (mg/L)	4.6	4.2	2.4	5.4	2.8	19.0	4.6	11.3	10.6	N/A	19	14.2	2.4	140
Dissolved Oxygen (mg/L)	7.8	-	7.4	6.6	5.5	5.8	6.0	5.2	-	N/A	21	6.0	3.3	7.9
Temperature (°C)	2.1	-	5.0	2.5	8.0	19.6	22.1	22.6	-	N/A	24	13.1	1.5	25
pH (standard units)	7.4	-	7.1	7.3	7.0	7.2	7.3	7.2	-	N/A	24	7.0	6.2	7.4
Oxidation Reduction Potential (mV)	130	-	89	134	204	345	310	232	-	N/A	24	210	25	345
Conductivity (uS)	99	-	114	105	386	366	194	416	-	N/A	23	310	99	1152
Surface Elevation	1.2	-	1.2	1.5	1.5	1.2	1.0	0.9	-	N/A	24	1.5	0.8	4
Total Flow (cfs)	2.9	-	2.6	5.9	4.8	2.9	1.0	0.9	-	N/A	24	3.1	0.6	7.6

NM Not Measured

Sampling program at Location #2 started in August 1995.

Surface elevation data for Location #2 is relative to the staff gauge elevation.



DRAWN BY: FAULK

CHECKED: C. CASITILUCCI APPROVED:

DRAWING:

FILE NO.:

PROJECT NO.:

DWG NO.:

SAMPLING  
LOCATION  
#1

SAMPLING  
LOCATION  
#2

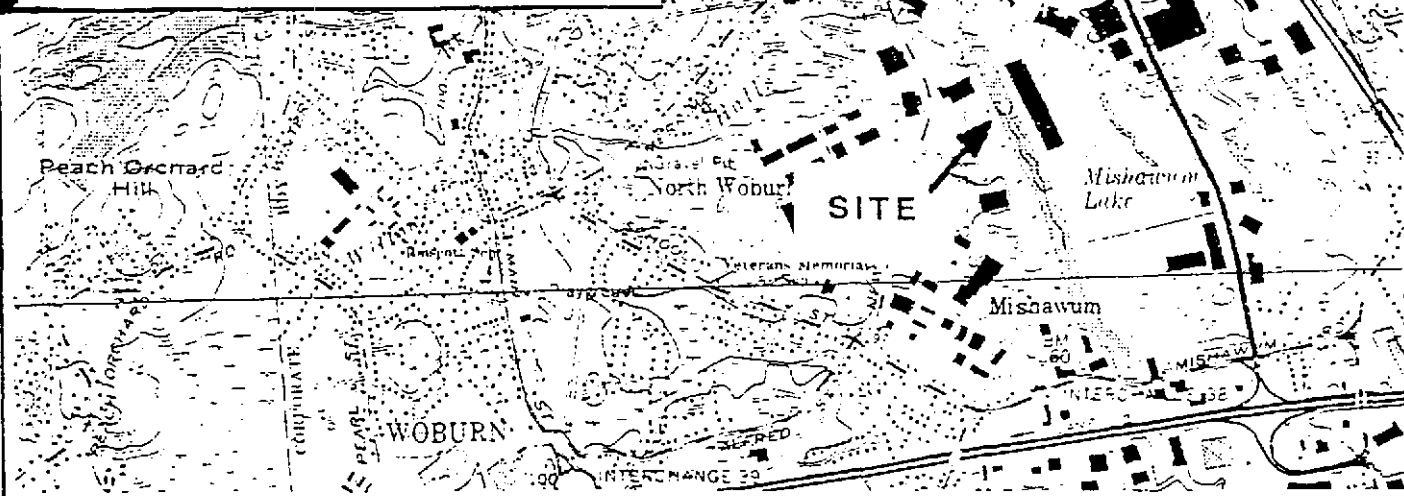
HIBBIA

DEC BUILDING

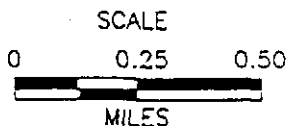
MISHAWUM ROAD

NOT  
TO  
SCALE

### LOCATION DETAIL



### QUADRANGLE LOCATION



SOURCE: WILMINGTON, MASSACHUSETTS 7.5 MINUTE U.S.G.S. TOPOGRAPHIC QUADRANGLE, 1979



GERAGHTY  
& MILLER, INC.  
Environmental Services

## SITE LOCATION

INDUSTRIPLEX  
WOBBURN, MASSACHUSETTS

FIGURE

1



# IEA

An Aquarion Company

IEA, Inc.  
149 Rangeway Road  
North Billerica, MA 01862

Phone 508-667-1400  
Fax 508-667-7871

Mr. Devin Kirkpatrick  
Geraghty & Miller  
One Corporate Drive  
Andover, MA 01810

August 5, 1997

Dear Mr. Kirkpatrick:

Please find enclosed the analytical results of the sample(s) received at our laboratory on July 21, 1997. This report contains sections addressing the following information at a minimum:

- sample ID correspondence table
- analytical results
- chain-of-custody (if applicable)
- definitions of data qualifiers and terminology

Client Project #	MA 0440.003	Client Project Name	ISRT
IEA Report #	G123A-085	Purchase Order #	N/A

Copies of this analytical report and supporting data are maintained in our files for a minimum of 3 years unless special arrangements are made. Unless specifically indicated, all analytical testing was performed at the IEA-Massachusetts laboratory.

We appreciate your selection of our services and welcome any questions or suggestions you may have relative to this report. Please contact your customer service representative at (508) 667-1400 for any additional information. Thank you for utilizing our services and we hope you will consider us for your future analytical needs.

I have reviewed and approved the enclosed data for final release.

Sincerely,

Michael F. Wheeler, Ph.D.  
Laboratory Director

IEA/American Environmental Network (MA)  
MA-DEP #MA038

MW/kg

h:\reports\forms\lconwin\rpt00101.ma

8/5/97, 10:00 am

Monroe,  
Connecticut  
203-261-4458

Schaumburg,  
Illinois  
708-705-0740

Whippany,  
New Jersey  
201-428-8181

Cary,  
North Carolina  
919-677-0090



**Sample ID Correspondence Table**

<b>Client Sample ID</b>	<b>IEA Sample ID</b>
HBHA#1 Unfiltered	G123A-085-01
R HBHA#1 Unfiltered	G123A-085-02
HBHA#2 Unfiltered	G123A-085-03
R HBHA#2 Unfiltered	G123A-085-04
HBHA#1 Filtered	G123A-085-05
R HBHA#1 Filtered	G123A-085-06
HBHA#2 Filtered	G123A-085-07
R HBHA#2 Filtered	G123A-085-08



# IEA

An Aquarion Company

## Definitions of Data Qualifiers and Terminology

A number of data qualifiers are widely used within the environmental testing industry and may be utilized in our data reports. The following definitions of these qualifiers are included as a service to our clientele. The majority of the qualifiers have evolved from the EPA contract laboratory program (CLP).

- B - This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to use caution when applying the results of this analyte.
- BQL - Below Quantitation Limit indicates the compound was not detected in the sample above the practical quantitation limit.
- D - Indicates the compound was diluted below the calibration range.
- E - Indicates that the concentration of the specific compound exceeded the calibration range of the instrument for that particular analysis.
- J - Indicates an estimated value. The compound is determined to be present in the sample based on GC/MS criteria, but the amount is less than the sample quantitation limit. IEA - MA GC/MS reports do not typically report J - marked results. If requested, J - marked results are provided and the report flagged to verify that the data was appropriately reviewed.
- MDL - The method detection limit is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero.
- NA - Not applicable or not available.
- ND - Indicates the compound or analyte was not detected in the sample above the method detection limit or the practical quantitation limit for the particular analysis.
- PQL - The practical quantitation limit is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine operating conditions.



# AEN - MA Laboratory Results

Client: Geraghty & Miller  
Project: MA0440.003/ISRT  
Report Date: 08/05/97

IEA ID: G123A-085  
Received: 07/21/97

IEA #	Client ID	Parameter	Results	Units	PQL	Date Analyzed	Analyst	Method
Total Metals								
01	HBHA #1 Unfiltered	Arsenic	0.0287	mg/L	0.0050	07/23/97	GMP	206.2/7060
01	HBHA #1 Unfiltered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
01	HBHA #1 Unfiltered	Total Suspended Solids	4.8	mg/L	1.0	07/24/97	CCV	160.2
Total Metals								
02	R HBHA #1 Unfiltered	Arsenic	0.0252	mg/L	0.0050	07/23/97	GMP	206.2/7060
02	R HBHA #1 Unfiltered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
02	R HBHA #1 Unfiltered	Total Suspended Solids	5.9	mg/L	1.0	07/24/97	CCV	160.2
Total Metals								
03	HBHA #2 Unfiltered	Arsenic	0.0302	mg/L	0.0050	07/23/97	GMP	206.2/7060
03	HBHA #2 Unfiltered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
	HBHA #2 Unfiltered	Total Suspended Solids	11.3	mg/L	1.0	07/24/97	CCV	160.2
Total Metals								
04	R HBHA #2 Unfiltered	Arsenic	0.0296	mg/L	0.0050	07/23/97	GMP	206.2/7060
04	R HBHA #2 Unfiltered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
04	R HBHA #2 Unfiltered	Total Suspended Solids	10.6	mg/L	2.0	07/24/97	CCV	160.2
Dissolved Metals								
05	HBHA #1 Filtered	Arsenic	0.0112	mg/L	0.0050	07/23/97	GMP	206.2/7060
05	HBHA #1 Filtered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
Dissolved Metals								
06	R HBHA #1 Filtered	Arsenic	0.0098	mg/L	0.0050	07/23/97	GMP	206.2/7060
06	R HBHA #1 Filtered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
Dissolved Metals								
07	HBHA #2 Filtered	Arsenic	0.0098	mg/L	0.0050	07/23/97	GMP	206.2/7060
07	HBHA #2 Filtered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010
Dissolved Metals								
08	R HBHA #2 Filtered	Arsenic	0.0118	mg/L	0.0050	07/23/97	GMP	206.2/7060
08	R HBHA #2 Filtered	Chromium	BQL	mg/L	0.030	07/23/97	JB	200.7/6010

## Comments:

PQL = Practical quantitation limit.  
BQL = Below quantitation limit.

QC REPORT

Report Date: 08/05/97

PARAMETER	BATCH ID	BLANK RESULT (mg/L)	SPIKED SAMPLE ID	MS RECOVERY (%)	MSD RECOVERY (%)	RPD (%)	DATE ANALYZED
Arsenic	072297-2	<0.0050	W100-284-01	N/C	N/C	N/C	07/23/97
Chromium	072297-1	<0.030	W100-284-01	98.5	101.0	2.5	07/23/97

Corresponding Samples: G123A-085-01, G123A-085-02, G123A-085-03, G123A-085-04, G123A-085-05, G123A-085-06,  
G123A-085-07, G123A-085-08

Comments: NC = Not Calculated, amount of analyte in sample was much greater than spike level.

# QC REPORT

Report Date: 08/05/97

Compounds	Initial Calibration Check (%)	Continuing Calibration Check (%)	Continuing Calibration Check (%)	LCS (%)	Date Analyzed
Arsenic	99.2	96.8	97.4	107.0	07/23/97
Chromium	100.3	102.5	101.2	102.0	07/23/97

Corresponding samples: G123A-085-01, G123A-085-02, G123A-085-03, G123A-085-04, G123A-085-05, G123A-085-06, G123A-085-07, G123A-085-08

# QC REPORT

Report Date: 08/05/97

Parameter	Blank Results (mg/L)	Duplicate Sample ID	Result 1 (mg/L)	Result 2 (mg/L)	RPD (%)	Date Analyzed
Total Suspended Solids	<1.0	G123A-085-04	10.4	10.6	1.9	07/24/97

**Corresponding Samples:** G123A-085-01, G123A-085-02, G123A-085-03, G123A-085-04

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:	Geraghty & Miller	IEA ID:	G123A-085-01
Project:	MA0440.003/ISRT	Sample:	HBHA #1 Unfiltered
Report Date:	07/23/97	Type:	Water
Collected:	07/21/97	Container:	VOA
Received:	07/21/97		
Analyzed:	07/22/97	Dilution Factor:	1
By:	GAM		

Number	Priority Pollutant Compounds	PQL (ug/L)	Result (ug/L)
1	Benzene	1	BQL
2	Chlorobenzene	1	BQL
3	1,2-Dichlorobenzene	1	BQL
4	1,3-Dichlorobenzene	1	BQL
5	1,4-Dichlorobenzene	1	BQL
6	Ethylbenzene	1	BQL
7	Toluene	1	BQL
8	Xylenes (Total)	1	BQL
9	Methyl-t-butylether	1	BQL

Surrogate Standard Recovery:

1,4-Difluorobenzene      109 %

Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:	Geraghty & Miller	IEA ID:	G123A-085-02
Project:	MA0440.003/ISRT	Sample:	R HBHA #1 Unfiltered
Report Date:	07/23/97	Type:	Water
Collected:	07/21/97	Container:	VOA
Received:	07/21/97		
Analyzed:	07/22/97	Dilution Factor:	1
By:	GAM		

Number	Priority Pollutant Compounds	PQL (ug/L)	Result (ug/L)
1	Benzene	1	BQL
2	Chlorobenzene	1	BQL
3	1,2-Dichlorobenzene	1	BQL
4	1,3-Dichlorobenzene	1	BQL
5	1,4-Dichlorobenzene	1	BQL
6	Ethylbenzene	1	BQL
7	Toluene	1	BQL
8	Xylenes (Total)	1	BQL
9	Methyl-t-butylether	1	BQL

Surrogate Standard Recovery:

1,4-Difluorobenzene      109   %

Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:	Geraghty & Miller	IEA ID:	G123A-085-03
Project:	MA0440.003/ISRT	Sample:	HBHA #2 Unfiltered
Report Date:	07/23/97	Type:	Water
Collected:	07/21/97	Container:	VOA
Received:	07/21/97		
Analyzed:	07/22/97	Dilution Factor:	1
By:	GAM		

Number	Priority Pollutant Compounds	PQL (ug/L)	Result (ug/L)
1	Benzene	1	BQL
2	Chlorobenzene	1	BQL
3	1,2-Dichlorobenzene	1	BQL
4	1,3-Dichlorobenzene	1	BQL
5	1,4-Dichlorobenzene	1	BQL
6	Ethylbenzene	1	BQL
7	Toluene	1	BQL
8	Xylenes (Total)	1	BQL
9	Methyl-t-butylether	1	BQL

Surrogate Standard Recovery:

1,4-Difluorobenzene      108   %

Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:	Geraghty & Miller	IEA ID:	G123A-085-04
Project:	MA0440.003/ISRT	Sample:	R HBHA #2 Unfiltered
Report Date:	07/23/97	Type:	Water
Collected:	07/21/97	Container:	VOA
Received:	07/21/97		
Analyzed:	07/22/97	Dilution Factor:	1
By:	GAM		

Number	Priority Pollutant Compounds	PQL (ug/L)	Result (ug/L)
1	Benzene	1	BQL
2	Chlorobenzene	1	BQL
3	1,2-Dichlorobenzene	1	BQL
4	1,3-Dichlorobenzene	1	BQL
5	1,4-Dichlorobenzene	1	BQL
6	Ethylbenzene	1	BQL
7	Toluene	1	BQL
8	Xylenes (Total)	1	BQL
9	Methyl-t-butylether	1	BQL

Surrogate Standard Recovery:

1,4-Difluorobenzene      108 %

Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:  
Project:  
Report Date: 07/23/97  
Collected:  
Received:  
Analyzed: 07/21/97  
By: GAM

IEA ID: Method Blank (07/21)  
Sample:  
Type: Water  
Container:

Dilution Factor: 1

Number	Priority Pollutant Compounds	PQL (ug/L)	Result (ug/L)
1	Benzene	1	BQL
2	Chlorobenzene	1	BQL
3	1,2-Dichlorobenzene	1	BQL
4	1,3-Dichlorobenzene	1	BQL
5	1,4-Dichlorobenzene	1	BQL
6	Ethylbenzene	1	BQL
7	Toluene	1	BQL
8	Xylenes (Total)	1	BQL
9	Methyl-t-butylether	1	BQL

Surrogate Standard Recovery:

1,4-Difluorobenzene 110 %

Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

Corresponding Samples: G123A-085-01, G123A-085-002, G123A-085-03, G123A-085-04

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:  
Project:  
Report Date: 07/23/97  
Collected:  
Received:  
Analyzed: 07/22/97  
By: GAM

IEA ID: L107-039-09 MS/MSD  
Sample:  
Type: Water  
Container:  
  
Dilution Factor: 1

Number	Priority Pollutant Compounds	MS (%)	MSD (%)	RPD (%)
1	Benzene	102	106	3.8
2	Chlorobenzene	100	104	3.9
3	1,2-Dichlorobenzene	100	103	3.0
4	1,3-Dichlorobenzene	110	114	3.7
5	1,4-Dichlorobenzene	95	105	10
6	Ethylbenzene	102	107	4.8
7	Toluene	99	104	4.9
8	Xylenes (Total)	93	99	6.2
9	Methyl-t-butylether	97	100	3.0

Surrogate Standard Recovery:

1,4-Difluorobenzene	113	114	0.9
---------------------	-----	-----	-----

Comments:

PQL == Practical quantitation limit.

BQL == Below quantitation limit.

Corresponding Samples: G123A-085-01, G123A-085-002, G123A-085-03, G123A-085-04

AEN - Massachusetts  
Analysis Report: EPA Method 8020A -Volatile Aromatics

Client:  
Project:  
Report Date: 07/23/97  
Collected:  
Received:  
Analyzed: 07/21/97  
By: GAM

IEA ID: Continuing Cal.  
Sample:  
Type: Water  
Container:

Dilution Factor: 1

Number	Priority Pollutant Compounds	Spike (ug/L)	Result (ug/L)
1	Benzene	50	57
2	Chlorobenzene	50	54
3	1,2-Dichlorobenzene	50	49
4	1,3-Dichlorobenzene	50	51
5	1,4-Dichlorobenzene	50	51
6	Ethylbenzene	50	57
7	Toluene	50	57
8	Xylenes (Total)	50	51
9	Methyl-t-butylether	50	53

Surrogate Standard Recovery:

1,4-Difluorobenzene	100	117
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Comments:

PQL = Practical quantitation limit.

BQL = Below quantitation limit.

Corresponding Samples: G123A-085-01, G123A-085-002, G123A-085-03, G123A-085-04

Project Number MA0440.003

Project Location ISRT

Laboratory IEA / AEN

Sampler(s)/Affiliation Diane Mosher  
G+M

					SAMPLE BOTTLE / CONTAINER DESCRIPTION										TOTAL
Lab #	SAMPLE IDENTITY	Code	Date/Time Sampled	Lab ID	BTEX 8020	Dissolved Arsenic	Dissolved Chromium	Total Arsenic	Total Chromium	TSS					
-01	HBHA #1		1130												
	Unfiltered	L	7/21/97		2		1	1							4
-05	HBHA #1		1130												
	Filtered	L	7/21/97			1									1
-02	RHBHA #1		1200												
	Unfiltered	L	7/21/97		2		1	1							4
-06	RHBHA #1		1200												
	Filtered	L	7/21/97			1									1
-03	HBHA #2		130												
	Unfiltered	L	7/21/97		2		1	1							4

Sample Code: L = Liquid; S = Solid; A = Air

Total No. of Bottles/  
Containers

Relinquished by: Diane Mosher  
Received by: [Signature]

Organization: G+M  
Organization: AEN

Date: 7/21/97 Time: 1450  
Date: 7/21/97 Time: 1450

Seal Intact?  
Yes No N/A

Relinquished by: [Signature]  
Received by: \_\_\_\_\_

Organization: \_\_\_\_\_  
Organization: \_\_\_\_\_

Date: 1/1/ Time: \_\_\_\_\_  
Date: 1/1/ Time: \_\_\_\_\_

Seal Intact?  
Yes No N/A

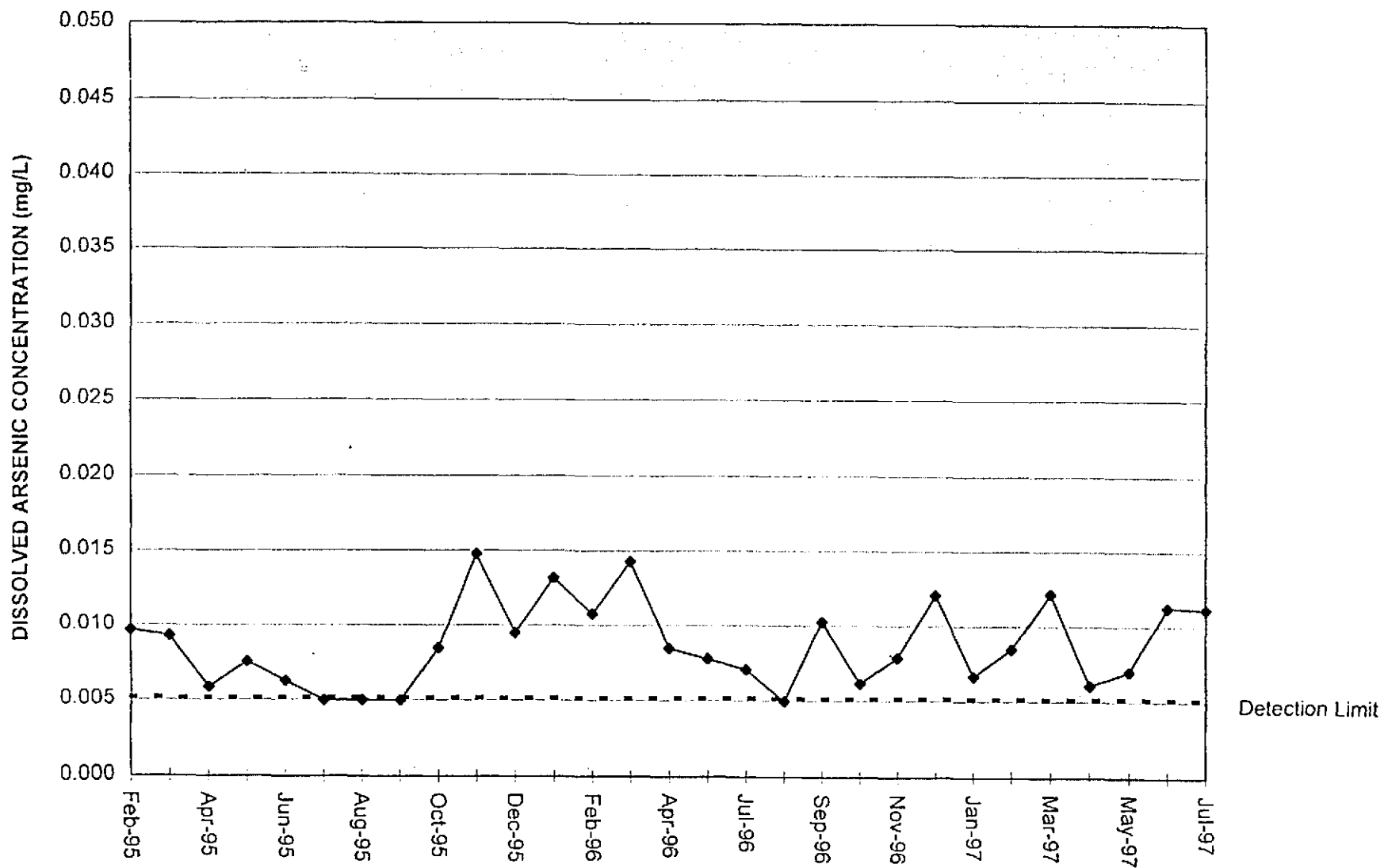
Special Instructions/Remarks: \_\_\_\_\_

Delivery Method: ☒ In Person ☐ Common Carrier ☐ Lab Courier ☐ Other \_\_\_\_\_



HBHA - WATER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

DISSOLVED ARSENIC CONCENTRATION PLOT (mg/L)

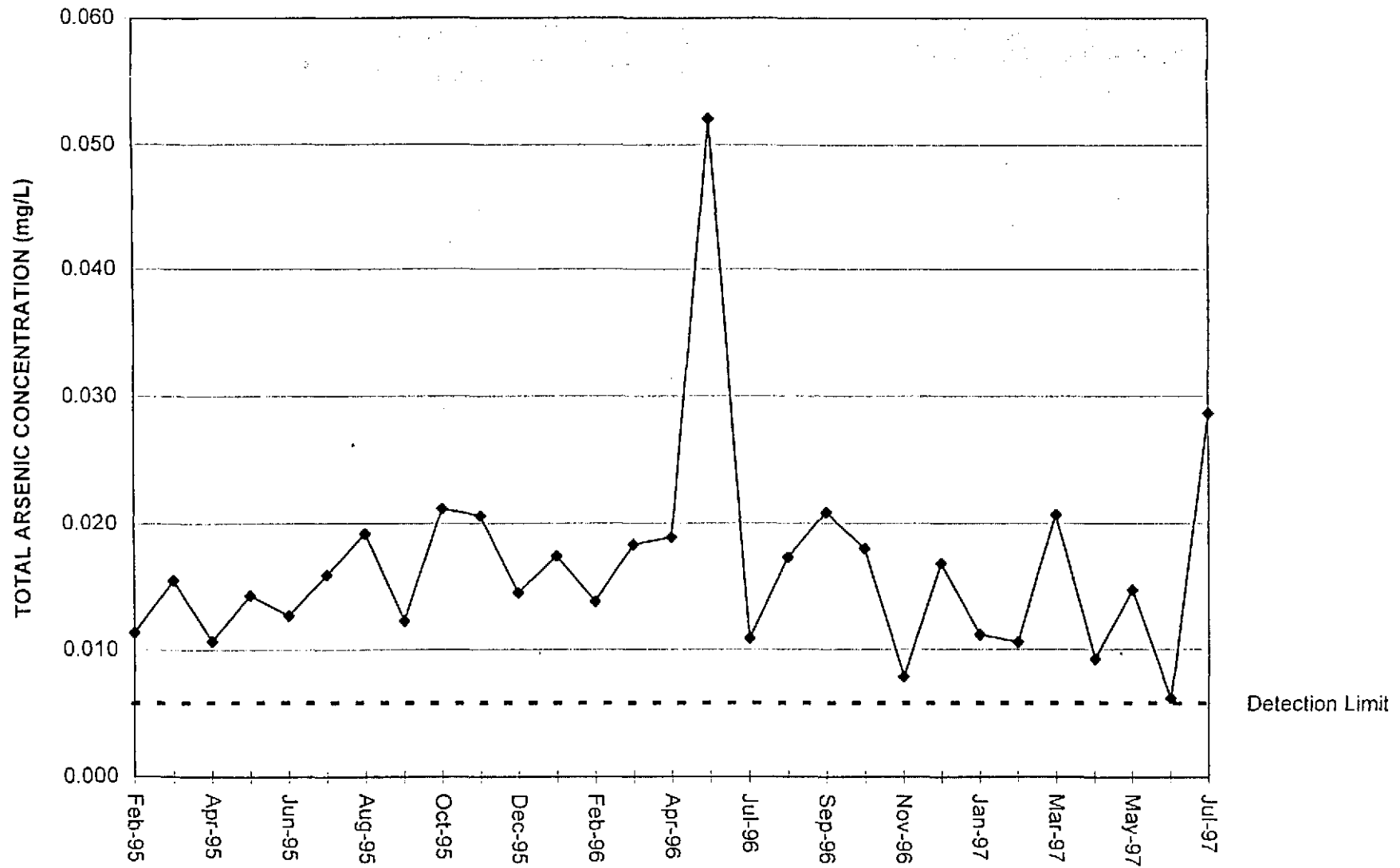


(Sampling Program at Location #1 Started in February 1995)



HBHA - W R SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

TOTAL ARSENIC CONCENTRATION PLOT (mg/L)

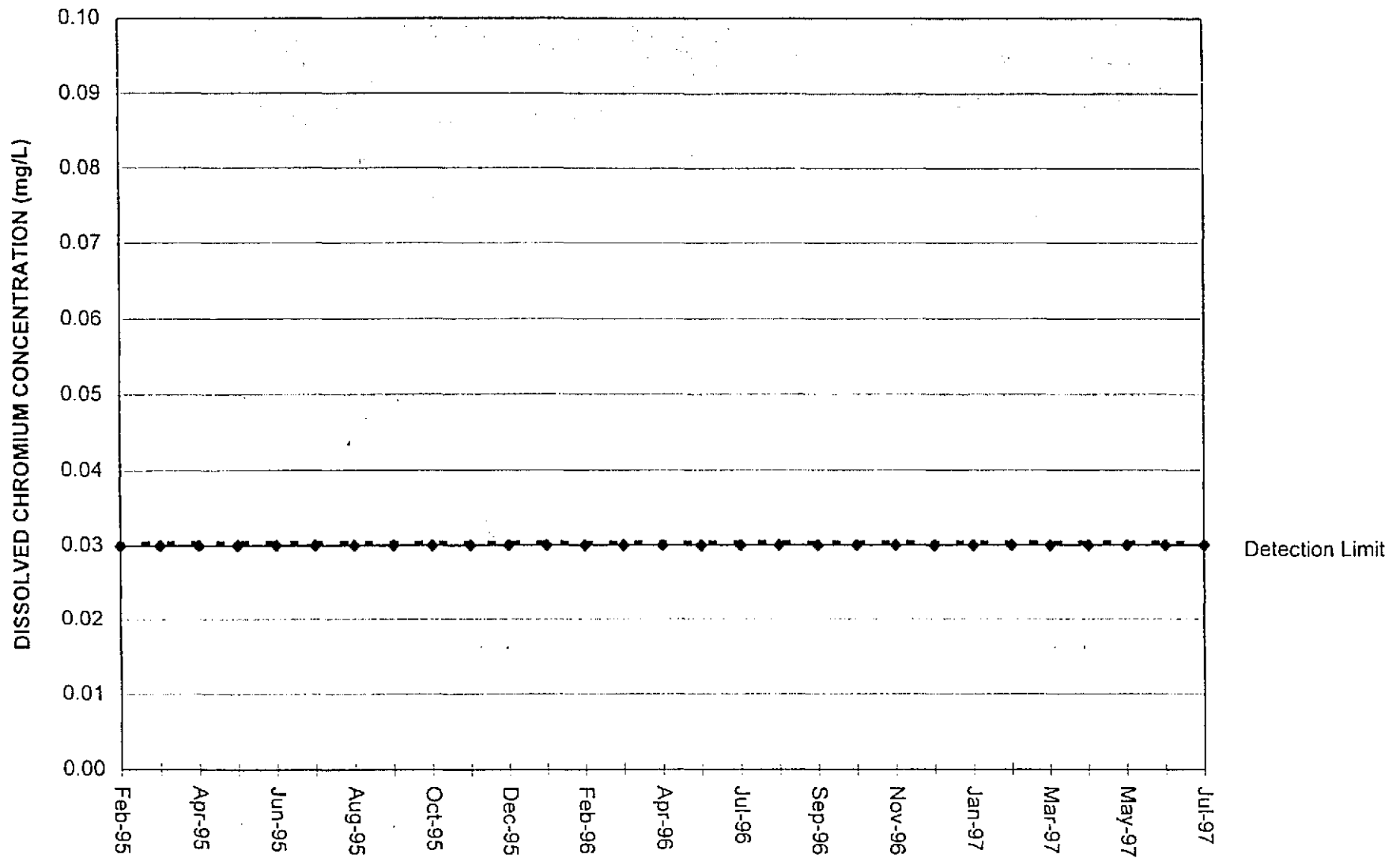


(Sampling Program at Location #1 Started in February 1995)



HBHA - WASTE WATER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

DISSOLVED CHROMIUM CONCENTRATION PLOT (mg/L)

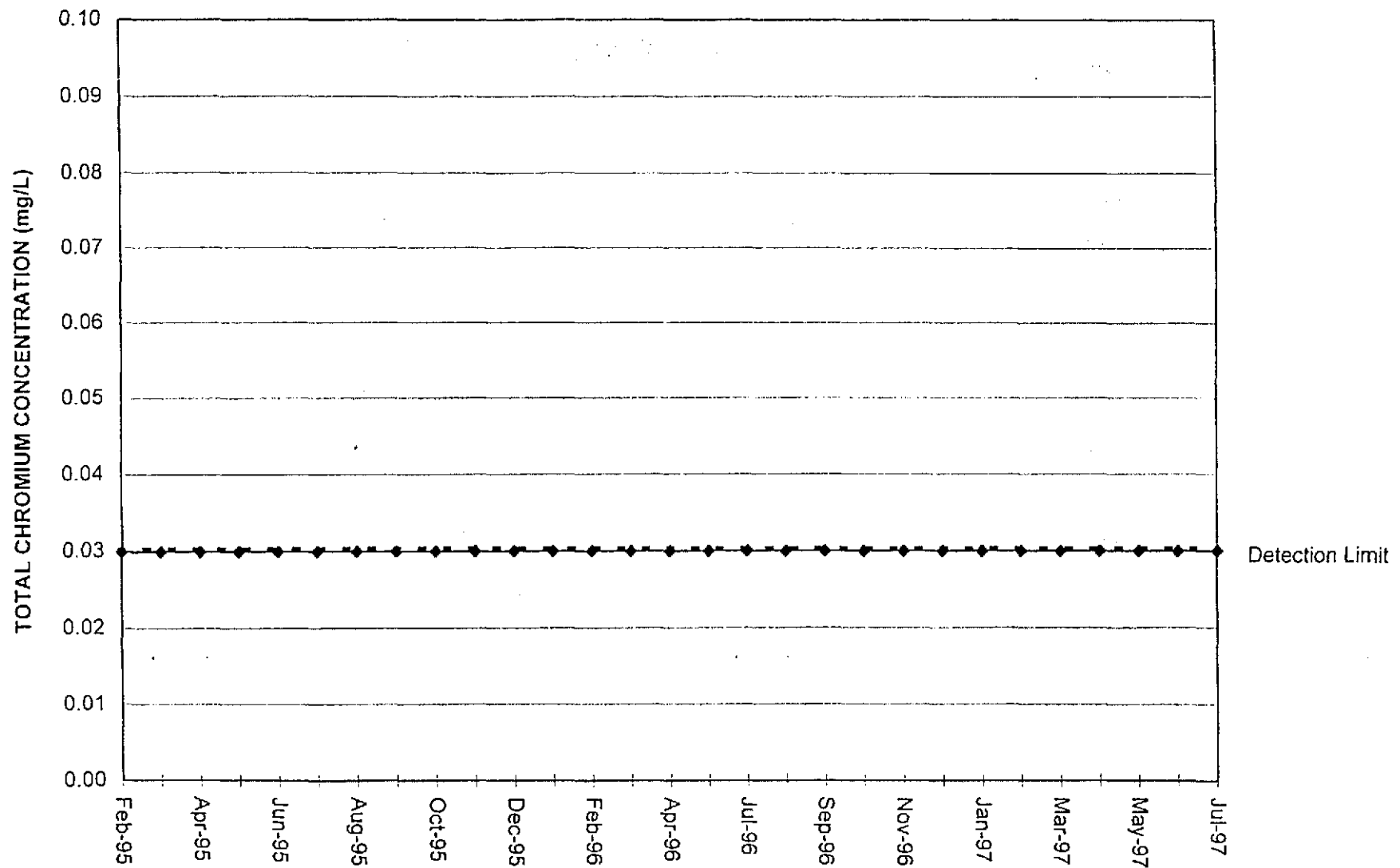


(Sampling Program at Location #1 Started in February 1995)



HBHA - W R SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

TOTAL CHROMIUM CONCENTRATION PLOT (mg/L)

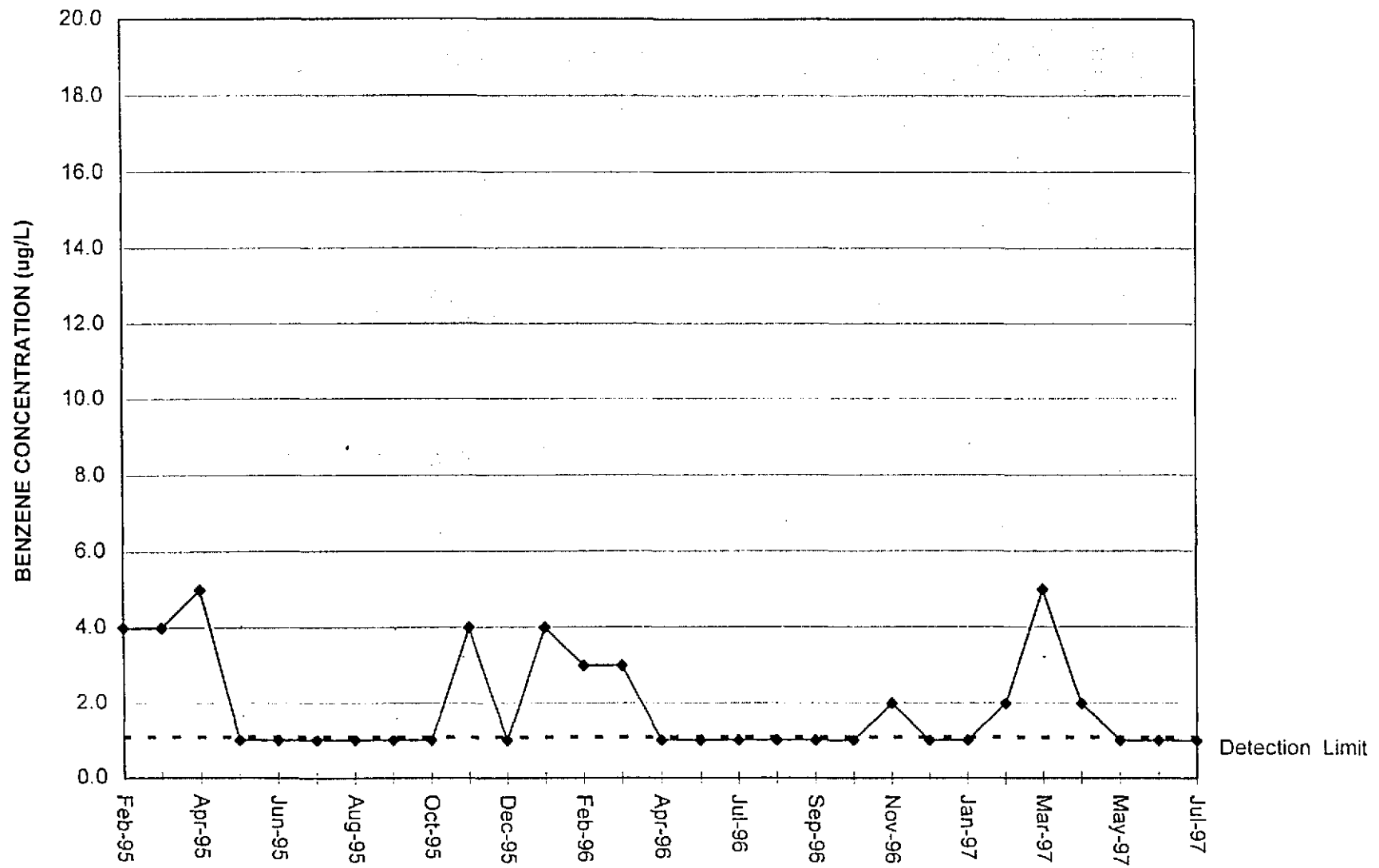


(Sampling Program at Location #1 Started in February 1995)



HBHA - WETTER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

BENZENE CONCENTRATION PLOT (ug/L)

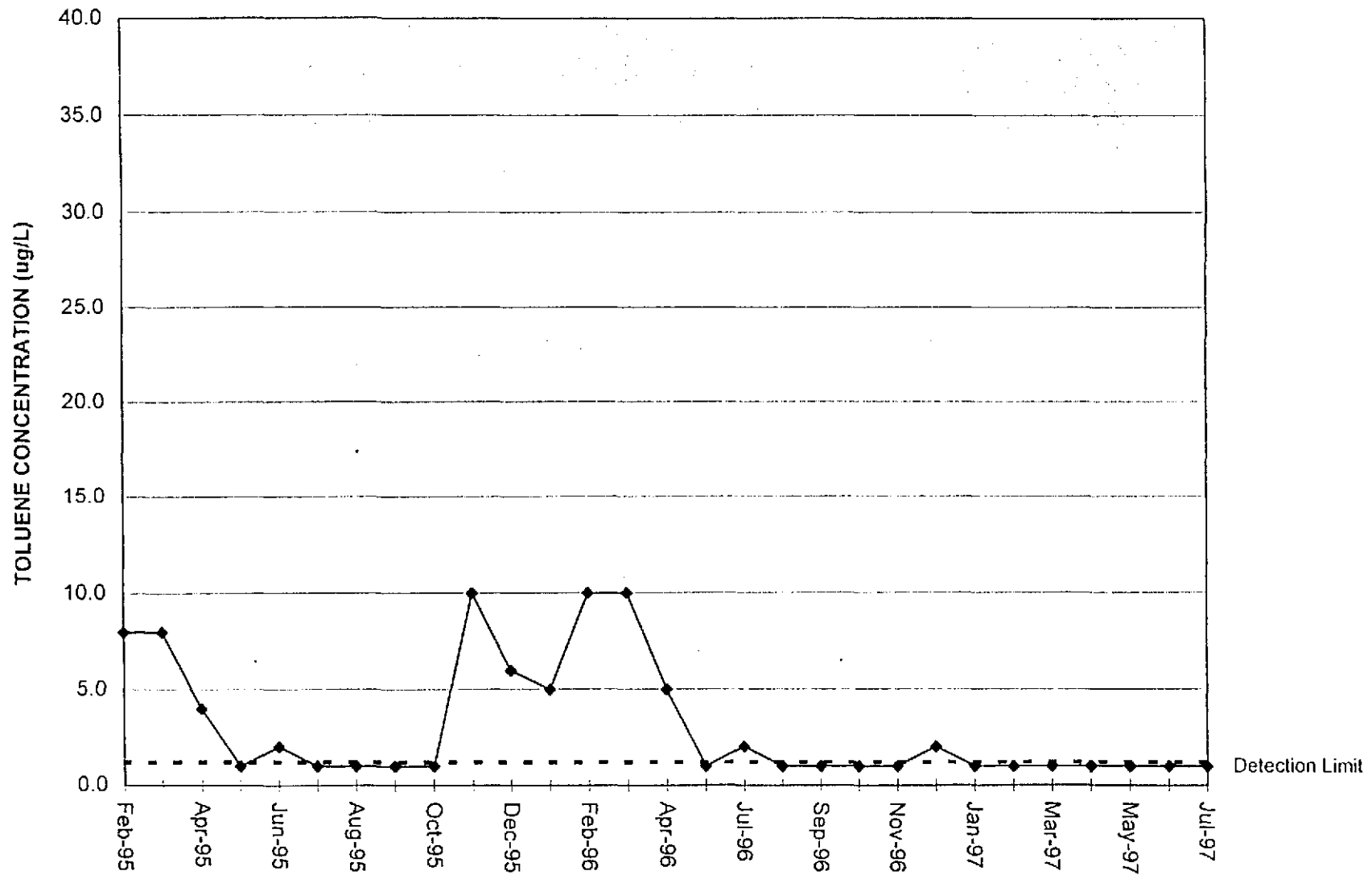


(Sampling Program at Location #1 Started in February 1995)



HBHA - W R SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #1

TOLUENE CONCENTRATION PLOT (ug/L)

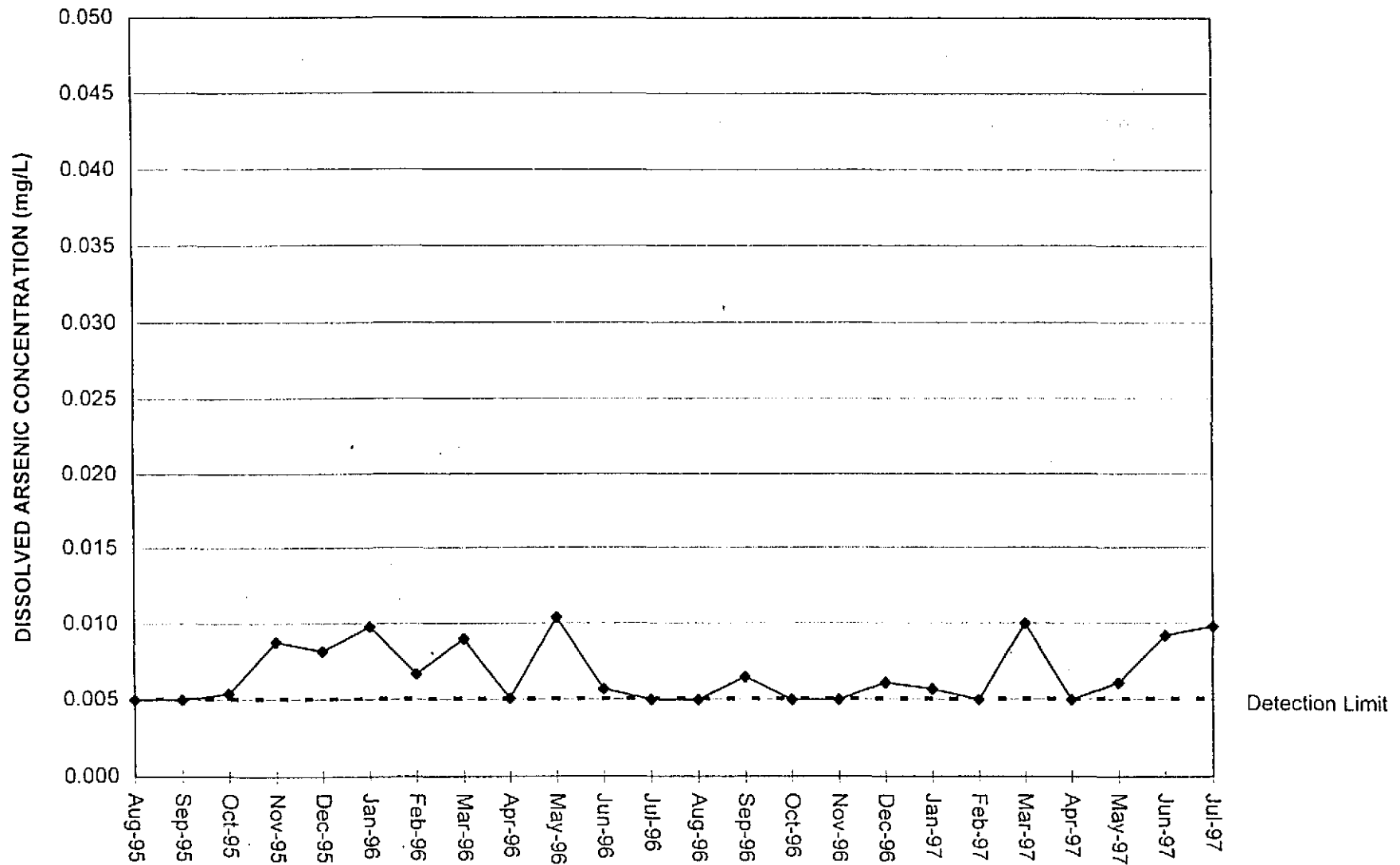


(Sampling Program at Location #1 Started in February 1995)



HBHA - WATER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

DISSOLVED ARSENIC CONCENTRATION PLOT (mg/L)

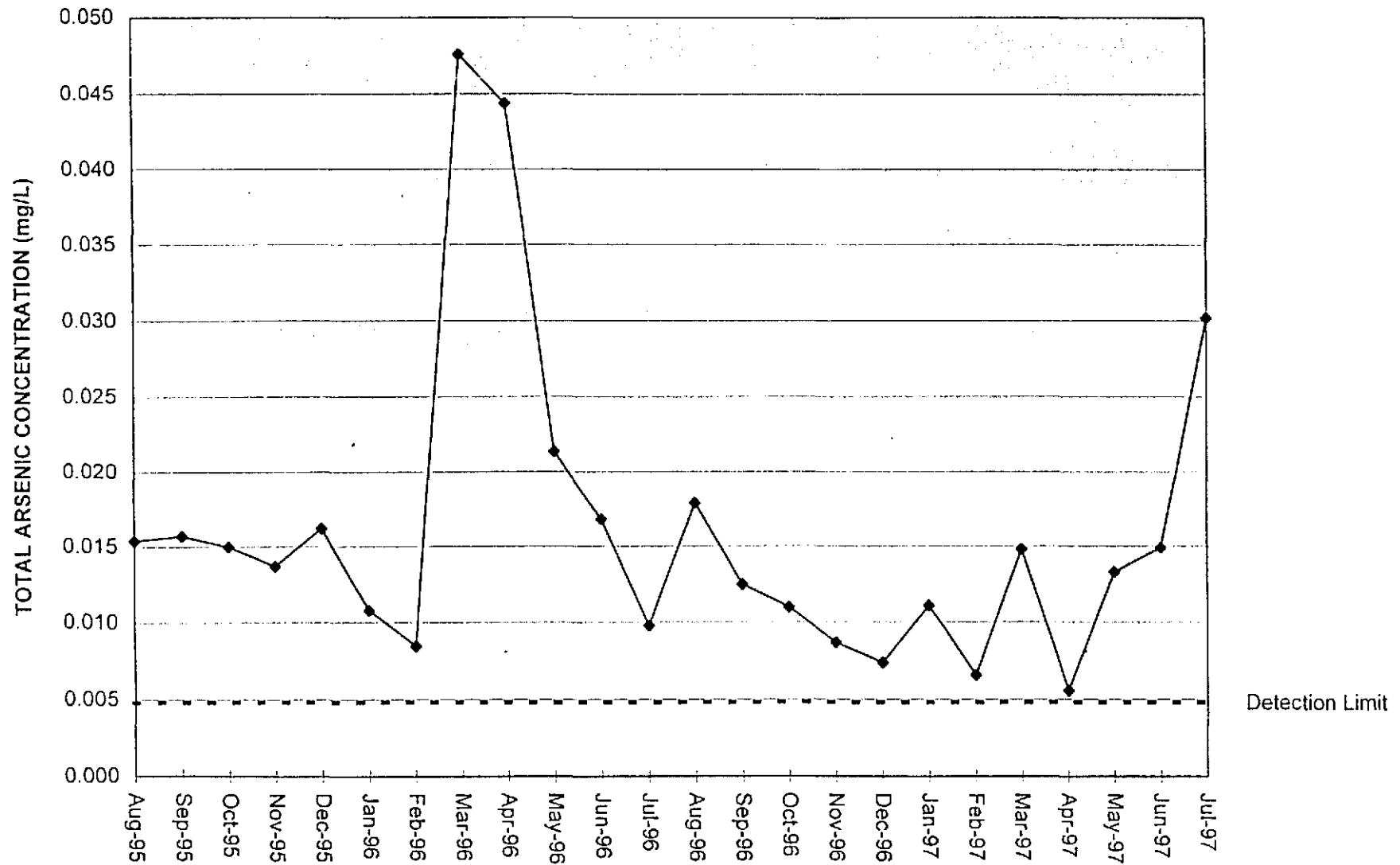


(Sampling Program at Location #2 Started in August 1995)



HBHA - W R SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

TOTAL ARSENIC CONCENTRATION PLOT (mg/L)

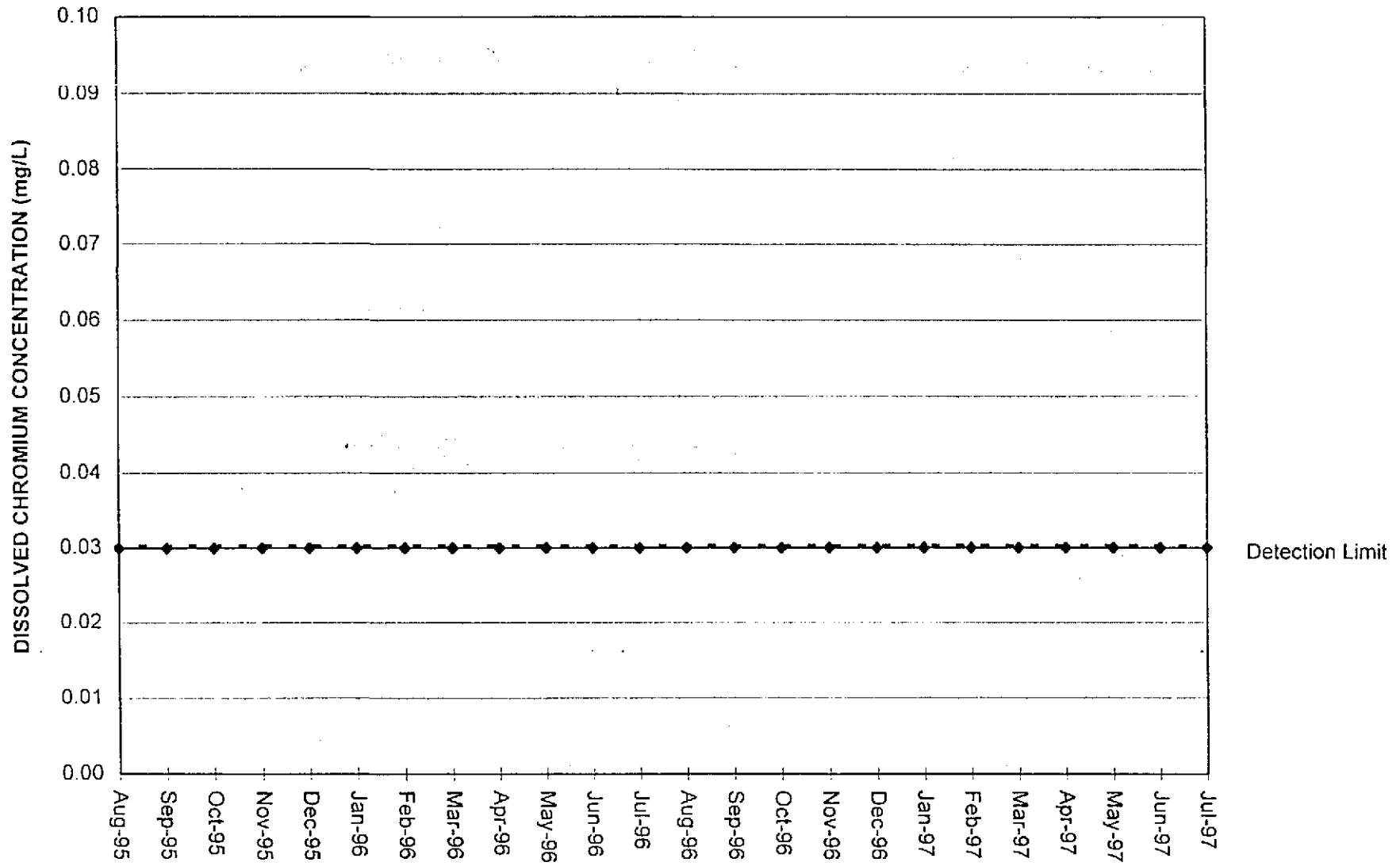


(Sampling Program at Location #2 Started in August 1995)



HBHA - WATER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

DISSOLVED CHROMIUM CONCENTRATION PLOT (mg/L)

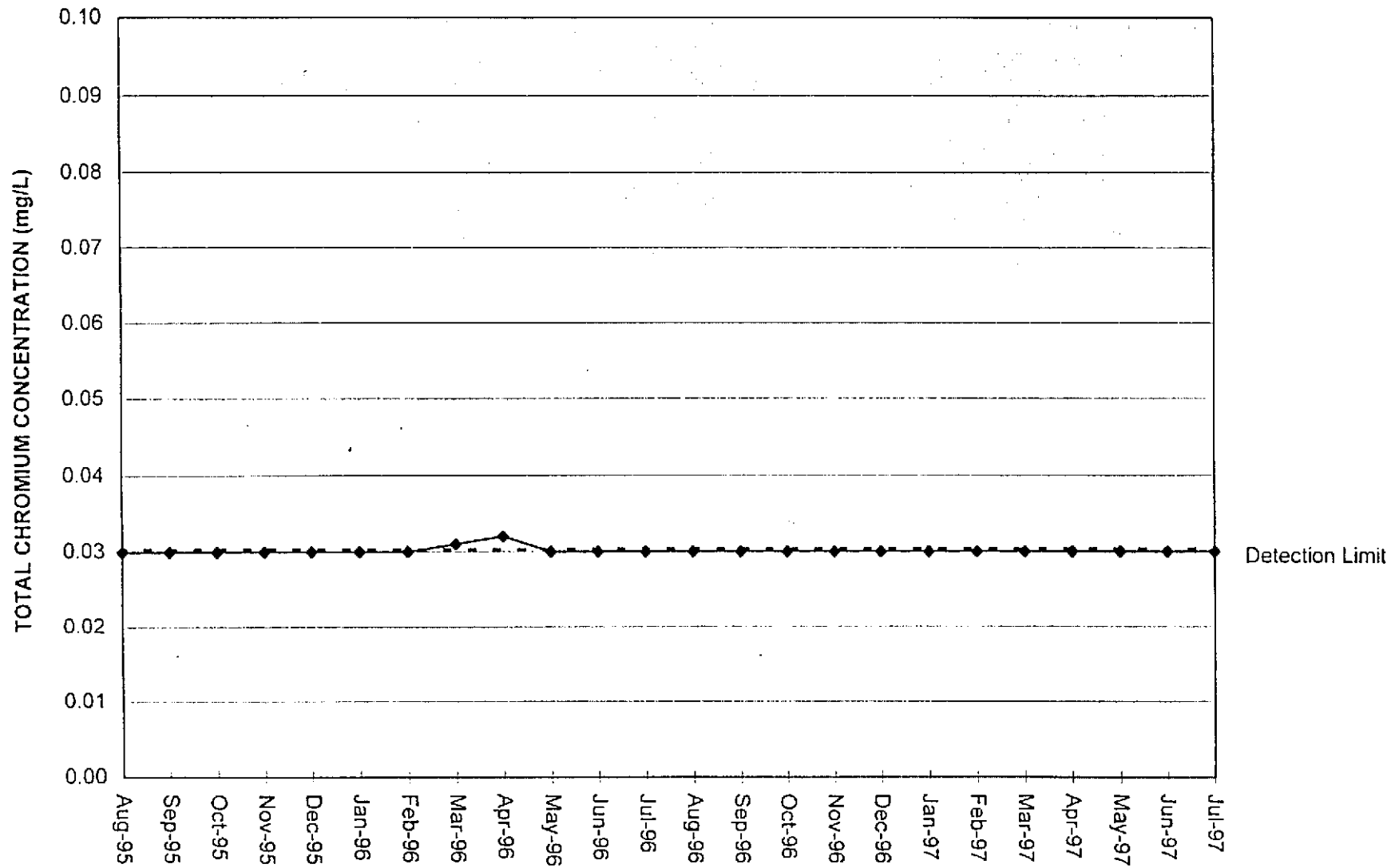


(Sampling Program at Location #2 Started in August 1995)



HBHA - WATER SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

TOTAL CHROMIUM CONCENTRATION PLOT (mg/L)

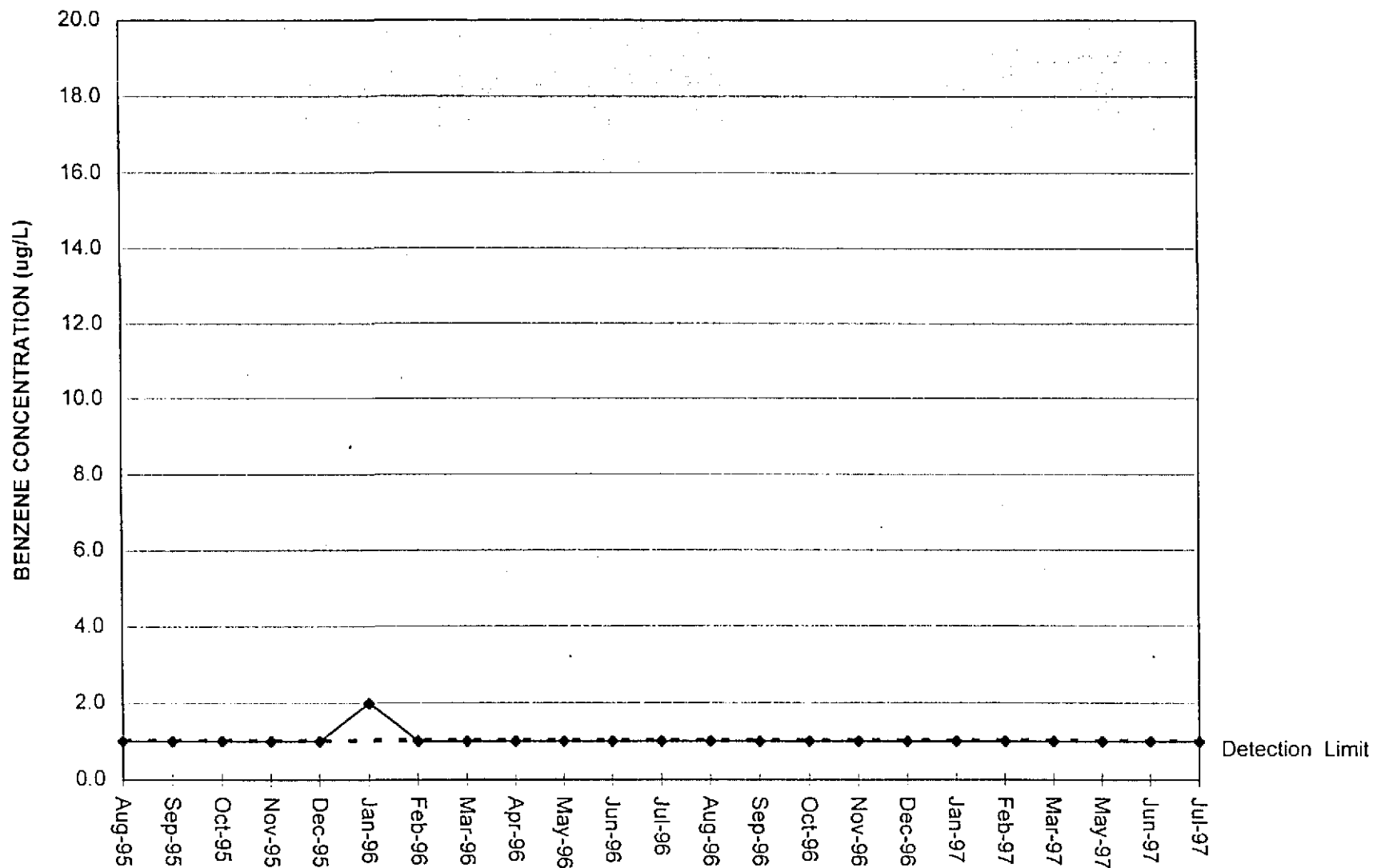


(Sampling Program at Location #2 Started in August 1995)



HBHA - WELL 2 SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

BENZENE CONCENTRATION PLOT (ug/L)

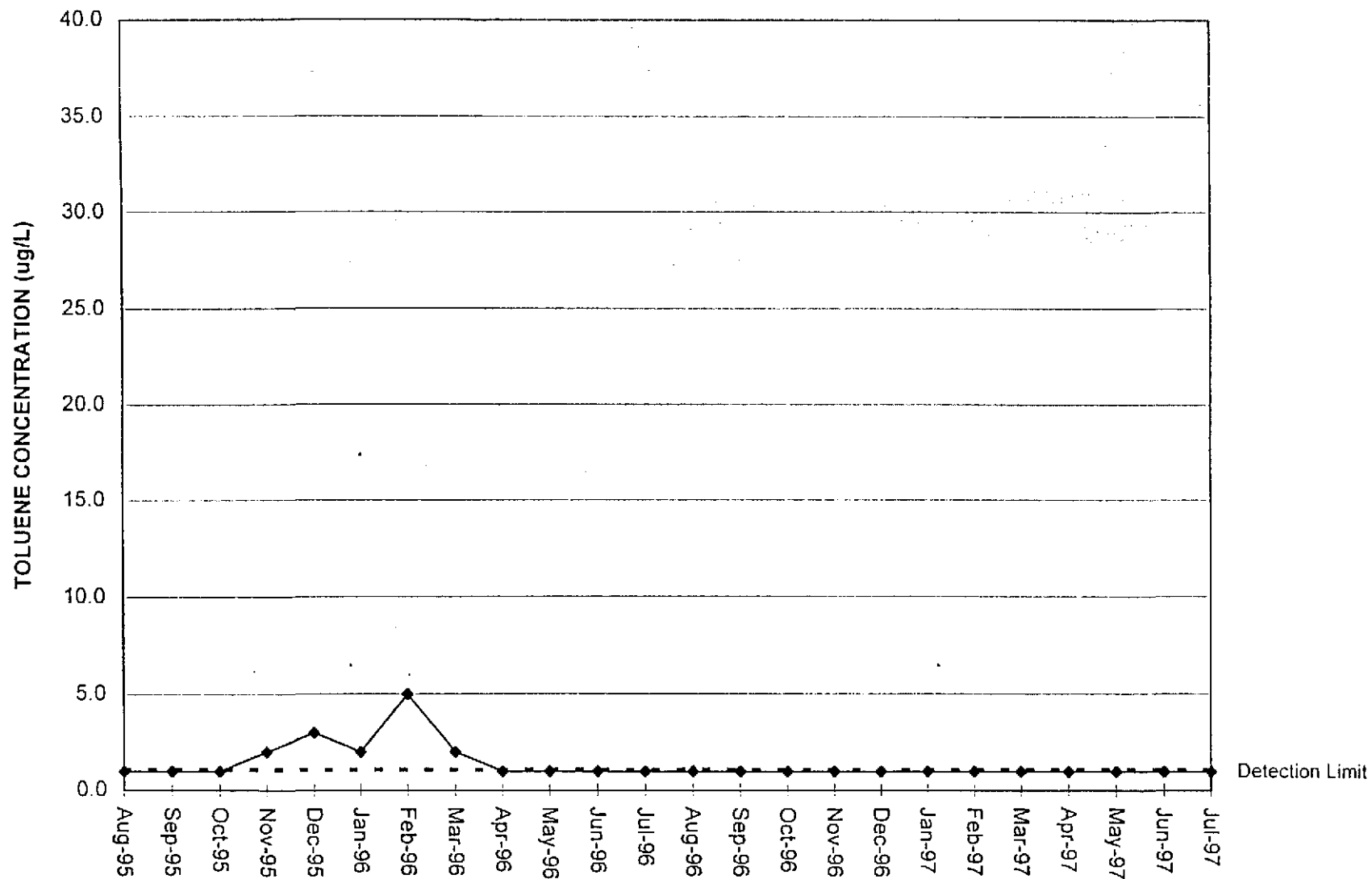


(Sampling Program at Location #2 Started in August 1995)



HBHA - WASTE REMEDIATION SAMPLING  
ISRT SITE, WOBURN, MASSACHUSETTS  
SAMPLING LOCATION #2

TOLUENE CONCENTRATION PLOT (ug/L)



(Sampling Program at Location #2 Started in August 1995)



SUBJECT: Flowrate Calculations

PROJECT: ISRT - HBHA

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BY: DSK DATE:

CHKD: DATE:

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Location # 1 July 1997 DATAStaff Gauge Reading = 0.81 ft.

Based on the baseline depth measurements made every 1 ft across the 26.0 ft width of the discharge channel, the cross-sectional flow area corresponding to a staff gauge reading of 0.81 ft. would be approximately 11.5 ft<sup>2</sup>

$$\therefore \text{AREA}_{\text{sect}} \approx 11.5 \text{ ft}^2$$

Velocity measured in center of channel (at surface) = 0.7 ft/sec

The average velocity throughout the cross-sectional flow area is assumed to be  $1/4$  of the measured velocity.

$$\therefore \bar{V} = (0.7 \text{ ft/sec}) / 4 = 0.18 \text{ ft/sec}$$

The Total Estimated Flowrate is equal to the average velocity multiplied by the cross-sectional flow area.

$$\begin{aligned} \therefore Q &= (\text{AREA}_{\text{sect}})(\bar{V}) \\ &= (11.5 \text{ ft}^2)(0.18 \text{ ft/sec}) \end{aligned}$$

$$Q = 2.1 \text{ ft}^3/\text{sec}$$

SUBJECT: FLOWRATE CALCS.

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LOCATION # 2 July 1997 DATA

The depth of flow measured in the 60-inch diameter round culvert was 4.9 inches.

$$\therefore \text{Depth Ratio (D)} = \frac{\text{depth of flow}}{\text{total diameter}} = \frac{4.9 \text{ in}}{60 \text{ in.}} = 0.0817$$


From the Table below, the percentage of Total Cross-Sectional Flow area corresponding to the depth ratio is 0.038.

D	% of Total	D	% of Total	D	% of Total
.02	.004799	.34	.299762	.66	.700238
.04	.013480	.36	.324061	.68	.724271
.06	.024509	.38	.348667	.70	.747702
.08	.037501	.40	.373539	.72	.770805
.10	.052025	.42	.398525	.74	.793498
.12	.067979	.44	.423749	.76	.815334
.14	.085114	.46	.449132	.78	.836923
.16	.103234	.48	.464560	.80	.857654
.18	.122421	.50	.500000	.82	.877579
.20	.142346	.52	.525440	.84	.896766
.22	.163077	.54	.550868	.86	.914886
.24	.184466	.56	.576251	.88	.932021
.26	.206502	.58	.601475	.90	.947975
.28	.229195	.60	.626461	.92	.962499
.30	.252298	.62	.651333	.94	.975491
.32	.275729	.64	.675939	.96	.986520
				.98	.995201

Multiplying the % of total by the Total Cross-Sectional Area of the 60-inch culvert pipe gives the flow area for the measured depth of flow

$$\text{AREA}_{\text{X SECT}} = \frac{0.038}{1} \times (\pi \times (5.0 \text{ ft})^2 / 4) = 0.8 \text{ ft}^2$$

$$\text{AREA}_{\text{X SECT}} = 0.8 \text{ ft}^2$$

Continued 

SUBJECT: FLOWRATE CALCS.

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Continued

JULY 1992 DATA

The Velocity measured in the culvert = 1.1 ft/sec

The average velocity is assumed to be equal to the measured velocity due to the turbulent nature of the flow.

$$\therefore \bar{V} = (1.1 \text{ ft/sec}) / 1 = \underline{1.1 \text{ ft/sec.}}$$

$$\boxed{\bar{V} = 1.1 \text{ ft/sec}}$$

The total estimated flowrate is equal to the average velocity multiplied by the cross-sectional flow area.

$$Q = (\text{AREA}_{\text{sect}})(\bar{V}) = (0.8 \text{ ft}^2)(1.1 \text{ ft/sec})$$

$$\boxed{Q = 0.9 \text{ ft}^3/\text{sec}}$$